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Description

TECHNICAL FIELD

The present invention is directed to a discharge lamp driving circuit, and more particularly to a circuit for operating a high-pressure gaseous discharge lamp without causing a harmful acoustic resonance.

BACKGROUND ART

There has been a growing demand for a discharge lamp operating circuit which is operated at a higher frequency in order to reduce the weight and bulk of the ballasting inductor. On the other hand, it is also known that discharge lamps, particularly high-pressure discharge lamps such as mercury high pressure lamps and sodium vapor lamps suffer from unstable discharge arcs que to "acoustic resonance" when operated at certain high frequencies. U.S. Pat. No. 4,291,254 with correspondance GB-A-2,045,554, proposed to select a stable frequency for avoiding such "acoustic resonance". However, such stable frequency is seen only in a limited range and differs from different kinds of lamps, thus reducing the flexibility of circuit design. Further, it is known that an extreme high frequency drive, for example, over 100 KHz may be effective for elimination of the "acoustic resonance", but this eventually results in considerable switching losses and noises which are not acceptable for the lamp operation. To this end, there has been proposed in Japanese Patent Publication (KOKAI) No. 60-262392 to drive the lamp by a composite lamp driving current having a repeating cycle of an alternating current interrupted by a dc current. This patent is based upon the finding that the repetitive interruption of the alternating current by the dc current can restrain the occurrence of the "acoustic resonance", even the alternating current is in a frequency range which would otherwise cause the "acoustic resonance". In this sense, this patent is advantageous in selecting a lamp drive frequency without having to consider the "acoustic resonance". Notwithstanding this advantage, the patent has a certain drawback in that two independent switching circuits, i.e., chopper and inverter circuits, are required for providing the dc current and the alternating current, respectively. This requires duplication of switching elements with consequent complexity in incorporating the respective drivers in circuits for the duplicated switching elements, thus eventually resulting in increased cost and bulk of the physical circuit assembly.

DISCLOSURE OF THE INVENTION

The present invention eliminates the above problem by commonly utilizing at least one switching element for chopper and inverter switching circuits and provides an improved discharge lamp driving circuit with simplified circuit arrangement.

It is therefore a primary object of the present invention to provide an improved discharge lamp driving circuit which is simple in configuration, yet preventing the acoustic resonance as well as assuring to make compact the physical arrangement of the circuit.

An improved discharge lamp driving circuit in accordance with the present invention comprises a dc (direct current) voltage source, chopper means, and inverter means. The chopper means comprises a first switching circuit which is coupled to the dc voltage source to provide therefrom a periodically interrupted current and smooth the same for producing a smoothed dc current.The inverter means comprises a second switching circuit which is also coupled to the dc voltage source for producing therefrom a high frequency alternating current. Included in the circuit is control means which is connected to the chopper means and the inverter means in order to apply to the discharge lamp a repeating cycle of a composite lamp driving current composed of the high frequency alternating current supplied from the inverter means and is interrupted by the smoothed dc current supplied from the chopper means.

A characterizing feature of the present invention resides in that the first and second switching circuits of the chopper and inverter means are arranged to have at least one common switching element which operates both in producing the dc current and the high frequency alternating current. With this result, the circuit configuration can be considerably simplified with consequent reduction in cost and bulk of the device.

In a preferred embodiment, the chopper means is configured in a bridge arrangement to apply to the discharge lamp the smoothed dc current which is reversed in polarity from one cycle to the subsequent cycle of the composite lamp driving current. Thus, the deterioration of lamp electrodes can be reduced to a minimum, thereby giving rise to an enhanced life time of the discharge lamp.

The lamp driving circuit of the present invention can be broadly classified into two types with and without a transformer which operates to apply the high frequency alternating current to the discharge lamp. In the former type, the first switching circuit of the chopper means comprises at least one switching element common to the second switching circuit of the inverter means. The common switching element is coupled in series circuit

with an inductor and a parallel combination of the discharge lamp and a bypass capacitor of which series circuit is connected across the dc voltage source. During a first period of time, the common switching element is controlled to turn on and off at a first high frequency to produce the interrupted current which is smoothed by the first inductor and of which high frequency component is bypassed through the bypass capacitor for giving the smoothed dc current to the discharge lamp within each cycle of the composite lamp driving current. The second switching circuit of the inverter means comprises a pair of first and second switching elements at least one of which is common to the first switching circuit of the chopper means. The first and second switching elements are connected in series across the dc voltage and is connected in circuit with a dc blocking capacitor and the transformer with a primary winding and a secondary winding which is inserted in series relation with the discharge lamp and in parallel relation with the bypass capacitor. The blocking capacitor is connected in series with the primary winding of the transformer and in parallel with one of the first and second switching elements to form therewith a series oscillating circuit. During a second period of time alternating with the above first period of time, the first and second switching elements are controlled to alternately turn on and off at a second frequency to provide a high frequency alternating current in the series oscillating circuit as repeating to charge and discharge the dc blocking capacitor, whereby inducing the corresponding high frequency alternating current in the circuit of the secondary winding and the discharge lamp to drive the discharge lamp by such high frequency alternating current within each cycle of the composite lamp driving current.

In the other type of the circuit without the transformer, the first and second switching circuits of the chopper and inverter means commonly includes a pair of first and second switching elements arranged in a half- or full-bridge configuration with a pair of capacitors or with a pair of like switching elements.The bridge has its input ends connected across the dc voltage source and has its output ends connected across a series circuit composed of an inductor and a parallel combination of the discharge lamp and a bypass capacitor. During a first period of time, one of the first and second switching elements is controlled to turn on and off at a first frequency with the other switching element being kept turned off to provide a dc current which is smoothed by the inductor and is removed of its high frequency component by the bypass capacitor for feeding the smoothed dc current to the discharge lamp within each cycle of the composite lamp driving current. During a second period of time alternating with the first period of time, the first and second switching elements are controlled to alternately turned on and off at a second high frequency in such a manner as to provide to the discharge lamp said high frequency alternating current within each cycle of said composite lamp driving current.The second high frequency is determined to be lower than the first high frequency to such an extent that the second high frequency alternating current is supplied to the discharge lamp within each cycle of the composite lamp driving current while allowing the second high frequency component to be substantially fed to the discharge lamp without being bypassed through the bypass capacitor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a discharge lamp driving circuit illustrating one basic version in accordance with the principle of the present invention;

FIG. 2 is a waveform chart illustrating a composite lamp driving current in a conceptual form obtained in the present invention;

FIG. 3 is a circuit diagram of a discharge lamp driving circuit in accordance with a first embodiment of the present invention;

FIG. 4 is a timing diagram of waveforms illustrating the operation of the two switching transistors shown in FIG. 3;

FIG. 5 is a waveform chart illustrating a composite lamp driving current in a conceptual form obtained in the circuit of FIG. 3;

FIG. 6 is a circuit diagram of a modification of FIG. 3;

FIG. 7 is a circuit diagram of a second embodiment of the present invention;

FIG. 8 is a timing diagram of waveforms illustrating the operation of the four switching transistors shown in FIG. 7

FIG. 9 is a timing diagram of waveforms illustrating another operation of the four switching transistors shown in FIG. 7 in accordance with a modification of the second embodiment;

FIG. 10 is a waveform chart illustrating a lamp driving current in a conceptual form obtained by the switching operation of FIG. 9;

FIG. 11 is a circuit diagram of a third embodiment of the present invention;

FIG. 12 is a timing diagram of waveforms illustrating the operation of the four switching transistors shown in FIG. 11;

FIG. 13 is a timing diagram of waveforms illustrating another operation of the four switching transistors shown in FIG. 11 in accordance with a modification of the third embodiment;

FIG. 14 is a circuit diagram of a fourth embodiment of the present invention;

FIG. 15 is a timing diagram of waveforms illustrating the operation of the two switching transistors shown in FIG. 14;

FIG. 16 is a waveform chart illustrating a composite lamp driving current in a conceptual form obtained by the switching operation of FIG. 15;

FIG. 17 is a circuit diagram of a fifth embodiment of the present invention;

FIG. 18 is a timing diagram of waveforms illustrating the operation of the three switching transistors shown in FIG. 17;

FIG. 19 is a circuit diagram of a sixth embodiment of the present invention;

FIG. 20 is a timing diagram of waveforms illustrating the operation of the two switching transistors shown in FIG. 19;

FIG. 21 is a circuit diagram of a seventh embodiment of the present invention;

FIG. 22 is a circuit diagram of an eighth embodiment of the present invention;

FIG. 23 is a timing diagram of waveforms illustrating the operation of the two switching transistors shown in FIG. 22;

FIG. 24 is a circuit diagram of a ninth embodiment of the present invention;

FIG. 25 is a circuit diagram of a tenth embodiment of the present invention;

FIG. 26 is a timing diagram of waveforms illustrating the operation of the four switching transistors shown in FIG. 25; and

FIG. 27 is a timing diagram of waveforms illustrating another operation of the four switching transistors shown in FIG. 25 in accordance with a modification of the tenth embodiment.

MODES FOR CARRYING OUT THE INVENTION

Referring now to FIG. 1, one version of a discharge lamp driving circuit in accordance with the present invention is shown in a general form for easy understanding of the principle of the present invention. The circuit comprises a switching section **1** which is connected across a dc voltage source V_1 and includes at least two switching elements or transistors collectively indicated in FIG. 1 as **S**. The switching section **1** has a first pair of output ends **1a** and **1b** between which is connected a series circuit of an inductor L_1 and a parallel combination of a discharge lamp **10** and a bypass capacitor C_1. Also provided at the switching section **1** is a second pair of output ends **1c** and **1d** between which is connected a circuit of a dc blocking capacitor C_2 and a transformer **T** with a primary winding L_{21} and a secondary winging L_{22}. The secondary winging L_{22} is coupled in series with the discharge lamp **10** in parallel relation with the bypass capacitor C_1. The switching section **1** is controlled, during a first period of time T_{DC} (t_1 - t_2), to repetitively interrupt the dc voltage at a first high frequency for providing a chopped voltage between the first pair of output ends **1a** and **1b**. The chopped voltage is then smoothed by the inductor L_1 and has its high frequency component bypassed through the bypass capacitor C_1 to thereby feed a smoothed dc current I_{DC} to the discharge lamp **10** during the first period T_{DC}, as shown in FIG. 2 which shows a composite lamp driving current **Ia** in a conceptual waveform. During a second period of time T_{HF} (t_2 - t_3) alternating with the first period of time T_{HF}, the switching section **1** is controlled to repetitively interrupt the dc voltage at a second high frequency in order to repeat producing a voltage between output ends **1c** and **1d** and shorting the same. While the positive voltage is developed across the output ends **1c** and **1d**, the voltage is applied through the dc blocking capacitor C_2 to the primary winding L_{21} of the transformer **T** so as to flow a current in one direction in the primary winding L_{21} as charging the blocking capacitor C_2. Upon subsequent shorting between the output ends **1c** and **1d**, the blocking capacitor C_2 discharges to feed an opposite current through the primary winding L_{21}. Consequently, the above repetition of developing the voltage and shorting between the output ends **1c** and **1d** will induce an alternating current with the second high frequency at the secondary winding L_{22} of the transformer **T** such that the resulting high frequency alternating current is caused to circulate through the closed loop of the lamp **10** and the bypass capacitor C_1 as it is blocked by the inductor L_1, whereby providing to the lamp the high frequency alternating current I_{AC} during the second period of time T_{HF}, as shown in FIG. 2. In this manner, the switching section **1** provides a repeated cycle of a composite lamp driving current composed of the high frequency alternating current I_{AC} interrupted by the dc current I_{DC}. With this result, the lamp **10** can be kept free from causing an acoustic resonance or instable lamp operation even if the alternating current has a high frequency which might cause such acoustic resonance when utilized alone. The second frequency of the alternating lamp current may be suitably selected to be equal to or different from the first frequency at which the switching section **1** is operated to chop the dc voltage. With the circuit arrangement of FIG. 1, it is possible to share at least one switching element in the switching section **1** which operates both in a chopper mode for providing the dc current I_{DC} and in an inverter mode of providing the high frequency alternating current I_{AC}. It is also noted in this connection that other components can be commonly and effectively utilized in the above two different operation modes. For example, the

bypass capacitor C_1, which acts to bypass the high frequency component of the dc current in the chopper mode, serves to complete the closed loop with the secondary winging L_{22} and the discharge lamp **10** to effectively apply to the discharge lamp **10** the alternating voltage developed at the secondary winding L_{22} in the inverter mode. Also the inductor L_1, which smoothes the chopped voltage in the chopper mode, serves to block the high frequency voltage and prevent it from being applying to the circuit other than the closed loop, thereby applying the high frequency voltage effectively to the discharge lamp **10** in the inverter mode. Further, the secondary winding L_{22} of the transformer **T**, which develops the high frequency voltage as a power source in the inverter mode, can serve to block the high frequency component of the chopped voltage in the chopper mode, assisting to bypass the high frequency component through the bypass capacitor C_1. The discharge lamp **10** may be a high pressure gaseous discharge lamp such as mercury high pressure discharge lamp with metal halogen additives, sodium vapor lamp, and the like, or may be a low pressure lamp.

The present invention is now discussed in more detail with reference to preferred embodiments. Like numerals designate like parts throughout the following embodiments for easy reference.

First embodiment (FIGS. 3 to 5)

In this embodiment, the circuit comprises a pair of first and second switching transistors Q_1 and Q_2 which are cooperative with a pair of capacitors C_3 and C_4 to form a half-bridge having its input ends connected across a dc voltage source V_1. Connected across the output ends of the half-bridge is a series circuit composed of an inductor L_1 and the parallel combination of a discharge lamp **10** and a bypass capacitor C_1. The first and second switching transistors Q_1 and Q_2 are cooperative with the series circuit to form a chopper which provides a dc current to the discharge lamp **10**. A transformer **T** is incorporated in the circuit with its primary winding L_{21} connected in series with a dc blocking capacitor C_2 across the second switching transistor Q_2 and with its secondary winding L_{22} inserted in series with discharge lamp **10** and in parallel with the bypass capacitor C_1. The series connection of the primary winding L_{21} and the blocking capacitor C_2 is cooperative with the first and second switching transistors Q_1 and Q_2 to form an inverter or series oscillating circuit which provides a high frequency alternating current to the discharge lamp **10**. As discussed in the below, the first and second switching transistors Q_1 and Q_2 are controlled to provide repeating cycles of a composite lamp driving current composed of the dc current fed from the chopper and the high frequency alternating current from the inverter, as shown in FIG. 5. Typical values for the above circuit are as follows. The voltage of the dc voltage source V_1 is 280 V, the bypass capacitor C_1 has a capacitance of 0.22 µF, the inductor L_1 has an inductance of 0.2 mH, the primary winging L_{21} has an inductance of 0.5 mH, and the blocking capacitor C_2 has a capacitance of 0.1 µF. The first and second switching transistors Q_1 and Q_2 are operated at 40 KHz both in the chopper and the inverter mode. The operation of the chopper is now explained with reference to FIG. 4. During each first period of time T_{DC} alternating with a second period of time T_{HF} one of the first and second switching transistors Q_1 and Q_2 is controlled to turn on and off at a first high frequency while the other switching transistor is kept turned off. For example, during the first period of time T_{DC} (t_1 - t_2) of FIGS. 4 and 5, the first switching transistor Q_1 repeats turning on and off at a frequency of 40 KHz while the second transistor Q_2 is kept turned off. When the first transistor Q_1 is on, the capacitor C_3 will discharge a current through a route of the first switching transistor Q_1, secondary winding L_{22}, discharge lamp **10**, and inductor L_1. When the first transistor Q_1 is turned off, the inductor L_1 acts to maintain a continuous flow of current in the same direction. Thus, the dc current from the capacitor C_3 is smoothed by the inductor L_1 and has its high frequency component bypassed through the bypass capacitor C_1 so as to feed the smoothed dc current to the discharge lamp **10**. During the first period of time T_{DC} (t_3 - t_4), the second switching transistor Q_2 turns on and off at the same frequency while the first switching transistor Q_1 is kept turned off, thereby producing the like dc current but in opposite polarity, as shown in FIG. 5. With this provision of reversing the polarity of the dc current from one cycle to the subsequent cycle of the composite lamp driving current, the discharge lamp **10** can have an elongated operation life.

The second period of time T_{HF} in which the inverter is active to provide the high frequency alternating current is initiated by driving to turn on and off one of the switching transistor which is kept turned off in the previous first time of period while keeping the other switching transistor turning on and off. For example, in the second period of time T_{HF} (t_2 - t_3), the second switching transistor Q_2, which has been off in the previous first time of period T_{DC}, begins to turn on and off while the first switching transistor Q_1 continues to turn on and off. During this period, the first and second switching transistors Q_1 and Q_2 are alternately turned on and off with a dead-time therebetween, in which both of

the switching transistors are simultaneously off, in order to provide the high frequency alternating current. The inverter operation in this period is explained in terms of the repeating sequence of the following four consecutive occurrences 1) to 4), as indicated in FIG. 4.

At the first occurrence 1), the second switching transistor Q_2 is turned on while the first switching transistor Q_1 is off such that the blocking capacitor C_2 which has been charged due to the previous turning on of first switching transistor Q_1 will begin discharging to cause a current to flow through the primary winding L_{21}, second switching transistor Q_2, and back to the blocking capacitor C_2. At the second occurrence 2) in which both of the first and second switching transistors Q_1 and Q_2 are off, the primary winding L_{21} in turn causes the current to continuously flow through a first diode D_1, dc voltage source V_1, blocking capacitor C_2 and back to the primary winding L_{21}. At the third occurrence 3), the first switching transistor Q_1 is on while the second switching transistor Q_2 is off so that the capacitor C_3 discharges its energy, causing a current to flow in the opposite direction through the first switching transistor Q_1, primary winding L_{21}, blocking capacitor C_2, capacitor C_4, and back to the capacitor C_3. At the fourth occurrence 4) where both of the first and second switching transistors Q_1 and Q_2 are off, the primary winding L_{21} acts to maintain the continuous flow of current through a second diode D_2, blocking capacitor C_2, and back to the primary winding L_{21}. In this sense, the first and second diodes D_1 and D_2, which are connected in antiparallel relation respectively to the first and second switching transistors Q_1 and Q_2, provide first and second bypass routes for continuously flowing the instantaneous currents discharged from the primary winding L_{21} at the second and fourth occurrences in which both of the switching transistors Q_1 and Q_2 are off.

Likewise, in the next second period of time T_{HF} (t_4 - t_5) which is initiated by turning on and off the first switching transistor Q_1 which has been on in the previous first time of period T_{DC}, the first and second switching transistors Q_1 and Q_2 are controlled to alternately turn on and off to produce the high alternating current through the primary winding L_{21}.

In this manner, during each second period of time T_{HF}, the high frequency alternating current continues to flow through the primary winding L_{21} to thereby induce at the secondary winding L_{22} the corresponding high frequency alternating current which circulates through the closed loop of the secondary winding L_{22}, discharge lamp **10**, and the bypass capacitor C_1 as the inductor L_1 acts to block such high frequency alternating current, whereby driving the discharge lamp **10** by thus obtained high frequency alternating current, as shown in FIG. 5.

It is noted at this connection that the second frequency is determined so that the inductor L_1 blocks such high frequency alternating current from circulating through the closed loop of the secondary winding L_{22}, discharge lamp **10**, and bypass capacitor C_1. Due to the above the circuit arrangement, the first and second switching transistors are commonly utilized both in the chopper mode of providing the dc current and in the inverter mode of providing the high frequency alternating current to the discharge lamp. In brief, the inverter mode of providing the high frequency alternating current is terminated by deactivating one of the switching transistors, which in turn immediately initiates the chopper mode of providing the dc current to the discharge lamp. Thus, by repeating the above operations, the high frequency alternating current can be repetitively interrupted by the dc current, as shown in FIG. 5, to thereby inhibit the occurrence of the acoustic resonance which would be otherwise develop due to the high frequency lamp driving.

The ratio of the period T_{DC} to the period of one complete cycle (T_{DC} + T_{HF}) of the composite lamp driving current may be suitably selected depending upon the kind of discharge lamp utilized for prevention of the acoustic resonance, as the suitable ratio will vary with different kinds of lamps.

Modification of the first embodiment (FIG. 6)

This modification shows a circuit arrangement which is identical to that of FIG. 3 except that the dc blocking capacitor C_2 is inserted between the primary winding L_{21} and the connection of the capacitors C_3 and C_4. The circuit provides the like composite lamp driving current of FIG. 5 by the like switching operations of FIG. 4, but in which each of the capacitors Q_3 and Q_4 is additive to the blocking capacitor C_2 to act as a voltage source to provide the high frequency alternating current during the second period of time T_{HF}. The other functions are identical to those of the first embodiment. In other words, during the second period of time for providing the high alternating current, the capacitors Q_3 and Q_4 can be made mainly responsible for producing the high frequency alternating current, while the blocking capacitor C_2 is responsible for blocking the dc current. Accordingly, the constant of the blocking capacitor C_2 can be determined relatively freely without taking into account for utilizing it as the voltage source for the alternating current, thus giving rise to an improved design flexibility of the circuit. Typical values for this circuit when operated on the dc voltage V_1 of 280 V are as follows. C_1 = 0.22 µF, L_1 = 0.22 mH, L_{21} =

0.9 mH, and C_2 = 0.01 µF. The first and second switching transistors Q_1 and Q_2 are operated at 40 KHz and 60 KHz, respectively in the chopper mode and the inverter mode.

Second embodiment (FIGS. 7 and 8)

Referring to FIG. 7, a second embodiment of the present invention is shown to be identical to the first embodiment of FIG. 3 except for utilizing additional third and fourth switching transistors Q_3 and Q_4 which are coupled with the first and second switching transistors Q_1 and Q_2 to form a chopper circuit of full-bridge configuration with third and fourth diodes D_3 and D_4 connected in antiparallel relation to the third and fourth switching transistors Q_3 and Q_4, respectively. Thus, as shown in FIG. 8, the one of the two diagonally disposed pairs of switching transistors Q_1, Q_4, and Q_2, Q_3 is rendered to be active while the other pair is inactive during the first period of time T_{DC} providing the dc current to the discharge lamp **10**. For example, during the first period of time T_{DC} (t_1 - t_2), the first switching transistor Q_1 is controlled to turn on and off at a first high frequency with the fourth switching transistor Q_4 being kept turned on, while the second and third switching transistors Q_2 and Q_4 are kept turned off. In this manner the switching transistors are controlled to provide the dc lamp current which is opposite in polarity from the period t_1 - t_2 to the period t_3 - t_4. In the inverter mode of providing the high frequency alternating current, or in the second period of time T_{HF} (t_2 - t_3, t_4 -t_5), the first and second switching transistors Q_1 and Q_2 are controlled in the same manner as in the first embodiment while the third and fourth switching transistors Q_3 and Q_4 are kept turned off, during which the first and second switching transistors Q_1 and Q_2 are cooperative with the primary winding L_{21} and the blocking capacitor C_2 to oscillate an alternating current through the primary winding L_{21} and the blocking capacitor C_2, as repeating the four occurrences which are similar to those discussed with reference to the first embodiment but differ in that the dc voltage V_1 will supply an energy to the series oscillating circuit of the primary winding L_{21} and the blocking capacitor C_2 when lhe first switching transistor Q_1 is on and the second switching transistor Q_2 is off.

Modification of the second embodiment (FIGS. 9 and 10)

The modification of the second embodiment utilizes the same circuit arrangement of FIG. 7, but operates the first and second switching transistors Q_1 and Q_2 as shown by the timing diagram of FIG. 9. As seen from FIG. 9, in the chopper mode of providing the dc current during the first period of time T_{DC} (t_1 - t_2, t_3 - t_4), both of the first and second switching transistors Q_1 and Q_2 are operative to alternately turn on and off such that during this period T_{DC} the discharge lamp **10** receives, in addition to the smoothed dc voltage from the dc voltage source V_1, the induced voltage developed at the transformer **T** due to the oscillation in the circuit of the primary winding L_{21} and the blocking capacitor C_2. Thus, the resulting dc lamp current may take the form of FIG. 10 in which the high frequency component is superimposed on the smoothed dc current (t_1 -t_2, t_3 - t_4).

Third embodiment (FIG. 11 and 12)

Referring to FIGS. 11 and 12, a third embodiment of the present invention is shown to comprise the same like circuit as in the second embodiment except that the blocking capacitor C_2 has its one end connected to the connection between the third and fourth switching transistors Q_3 and Q_4. The switching transistors Q_1 to Q_4 are controlled to turned on and off in accordance with a timing diagram of FIG. 12 to provide the like composite lamp driving current as shown in FIG. 5 for the first embodiment. In the chopper mode, the two diagonally disposed switching transistors, for example, Q_1 and Q_4, are controlled to turn on and off in a synchronized manner while the other two switching transistors, for example, Q_2 and Q_3 are kept turned off during each first period of time T_{DC} in order to provide the dc current to the discharge lamp **10**. Due to the synchronous operation of the diagonally disposed switching transistors Q_1, Q_4 and Q_2, Q_3 in the chopper mode, the inductor L_1 acts upon the subsequent turning off of the all switching transistors to cause the instantaneous dc current to continuously flow through a closed loop to the dc voltage supply V_1, thus feeding back the energy thereto. For example, when all of the switching transistors are turned off immediately after the first and fourth switching transistors Q_1 and Q_4 being turned on, the inductor L_1 cause the current to flow through the diode D_3, dc voltage source V_1, diode D_2, secondary winding L_{22}, discharge lamp **10** and back to the inductor L_{21}. On the other hand when all the switching transistors are turned off after the second and third switching transistors Q_2 and Q_3 being simultaneously turned on, the instantaneous current from the inductor L_{21} flows through the discharge lamp **10**, the secondary winding L_{22}, diode D_1, dc voltage source, diode D_4, and back to the inductor L_{21}.

In the inverter mode of providing the high frequency alternating current during the second period of time T_{HF} (t_2 - t_3, t_4 - t_5), the two switching transistors, for example, Q_1 and Q_4 in one diag-

onally disposed pair are controlled to simultaneously turn on and off while the switching transistors Q_2 and Q_3 in the other pair are controlled to simultaneously turn on and off in an alternating manner therewith. Thus, the alternating current appears in the series oscillating circuit including the primary winging L_{21} and the blocking capacitor C_2 with no substantial direct current being caused to flow through the discharge lamp **10** and the inductor L_1, whereby inducing at the secondary winding L_{22} the high frequency alternating current which circulates the closed loop of the secondary winding L_{22}, discharge lamp **10**, and bypass capacitor C_1. Also in the inverter mode, when all the switching transistors are simultaneously turned off, the primary winding L_{21} acts to fed back its accumulated energy to the dc voltage V_1 through the diodes D_3 and D_2 or the diodes D_1 and D_4.

Modification of the third embodiment (FIG. 13)

A modification of the third embodiment utilizes the same circuit of FIG. 11 but in which the switching transistors Q_1 to Q_4 are controlled in a somewhat different manner from the third embodiment. As shown in FIG. 13, the difference is seen in that, during first period of time T_{DC} (chopper mode), the first switching transistor Q_1 is controlled to turn on and off while the fourth switching transistor Q_4 is kept turned on (t_1 - t_2), and the third switching transistor Q_3 is controlled to turn on and off while the second switching transistor Q_2 is on (t_3 - t_4). Thus, upon the turning off of the first switching transistor Q_1, the switching transistor Q_4 is cooperative to the diode D_2 to form a closed loop including the inductor L_1 for circulating therethrough the current which is otherwise fed back to the dc voltage source V_1 through the diodes D_3 and D_2 as seen in the third embodiment. Likewise, upon turning off of the third switching transistor Q_3, the second switching transistor Q_2 is cooperative with the diode D_4 to circulate the current which is otherwise fed to the dc voltage source V_1 through the diodes D_1 and D_4 as seen in the third embodiment.

Fourth embodiment (FIGS. 14 to 16)

A fourth embodiment of the present invention comprises first and second switching transistors Q_1 and Q_2 connected across the dc voltage source V_1 with first and second diodes D_1 and D_2 connected in antiparallel respectively with the first and second switching transistors Q_1 and Q_2. The inductor L_1 is connected in series with a parallel combination of the discharge lamp **10** and bypass capacitor C_1, which series-parallel combination is connected in parallel with the second switching transistor Q_2. Also included in the circuit is the transformer **T** of which primary winding L_{21} is connected in series with the dc blocking capacitor C_2 across the second switching transistor Q_2. The secondary winding L_{22} is inserted in series with the discharge lamp **10** in parallel with the bypass capacitor C_1. In this circuit, the chopper is defined by the first switching transistor Q_1, and the series-parallel combination of the inductor L_1, discharge lamp **10**, bypass capacitor C_1, as enclosed in dotted lines **CH** in FIG. 14. Also, as enclosed in phantom lines **IV** in the figure, the inverter is defined by, in additions to the above components common the to the chopper, the second switching transistor Q_2 and the series circuit of the primary winding L_{21} and the blocking capacitor C_2, and the secondary winding L_{22}.

In operation, the first and second switching transistors Q_1 and Q_2 are controlled in a manner as shown in FIG. 15 to provide a composite lamp driving current of FIG. 16. That is, in the chopper mode during the first period of time T_{DC} (t_1 - t_2 and t_3 - t_4), the first switching transistor Q_1 is driven to turn on and off at a first high frequency to provide the chopped dc voltage which is smoothed by the inductor L_1 and of which the high frequency component is bypassed through the bypass capacitor C_1 to allow the flow of the resulting smoothed dc current to the discharge lamp **10**. In the inverter mode during the second period of time T_{HF} (t_2 -t_3), the first and second switching transistors Q_1 and Q_2 are driven to alternately turn on and off with a dead-time therebetween at a second high frequency, which may be equal to or different from the first high frequency, to cause an oscillating current through the circuit of the primary winding L_{21} and the blocking capacitor C_2 as repeating to charge and discharge the blocking capacitor C_2 in the same manner as effected in the previous embodiments. Thus, there is developed at the secondary winding L_{22} the induced current which will circulate through the closed loop of the secondary winding L_{22}, discharge lamp **10**, and the bypass capacitor C_1 as the inguctor L_1 acts to block such high frequency alternating current. In the inverter mode, the current flowing to the inductor L_1 is kept at a minimum by suitably selecting the values for the inductor L_1, bypass capacitor C_1, the secondary winding L_{22}, and the driving frequency or the second frequency at which the first and second switching transistors Q_1 and Q_2 are operated.

Fifth embodiment (FIGS. 17 to 19)

The discharge lamp driving circuit comprises the first and second switching transistors Q_1 and Q_2 connected across the dc voltage source V_1 with first and second diodes D_1 and D_2 connected in antiparallel relation respectively to the first and

second switching transistors Q_1 and Q_2. A third switching transistor Q_3 is connected in series with the inductor L_1 and the parallel combination of the discharge lamp **10** and the bypass capacitor C_1 across the first switching transistor Q_1. The transformer **T** is connected in circuit with its primary winding L_{21} connected in series with the blocking capacitor C_2 across the second switching transistor Q_2 and with its secondary winding L_{22} inserted in series with the discharge lamp **10** and in parallel with the bypass capacitor C_1. In this embodiment, the chopper is defined by the second and third switching transistors Q_2 and Q_3, the series-parallel circuit of inductor L_1, discharge lamp **10** and bypass capacitor C_1, as enclosed in the dotted lines **CH** in FIG. 17, while the inverter is defined by, in addition to the second switching transistor Q_2, the parallel combination of discharge lamp **10** and bypass capacitor C_1 common to the chopper, the transformer **T** and the blocking capacitor C_2, as enclosed in phantom lines **IV** in the figure. These switching transistors Q_1, Q_2, and Q_3 are controlled in accordance with a timing chart of FIG. 18 so as to provide the like composite lamp driving current as seen shown in FIG. 16 of the fourth embodiment. That is, in the chopper mode during the period T_{DC} (t_1 - t_2 and t_3 - t_4), the second switching transistor Q_2 is driven to turn on and off at a first high frequency while the first and third switching transistors Q_1 and Q_3 are turned off and on, respectively, whereby providing the smoothed dc current to the discharge lamp **10** in the same manner as in the fourth embodiment. In the inverter mode during the period T_{HF} (t_2 - t_3), the first and second switching transistors Q_1 and Q_2 are driven to alternately turn on and off with a dead-time therebetween at a second high frequency which may be equal to or different from the first high frequency, in order to produce an high frequency alternating current through the primary winging L_{21} and consequently circulate the resulting high frequency alternating current through the closed loop of secondary winding L_{22}, discharge lamp **10**, and bypass capacitor C_1, in the same manner as seen in the previous fourth embodiment. In the inverter mode, the third switching transistor Q_3 is kept turned off so that the discharge lamp **10** will not receive the current directly from the blocking capacitor C_2 or from the dc voltage source V_1.

Sixth embodiment (FIGS. 19 and 20)

Referring to FIG. 19, a sixth embodiment of the present invention is shown to comprise the first and second switching transistors Q_1 and Q_2 which are coupled with a pair of capacitors Q_3 and Q_4 in a half-bridge configuration having its input ends connected across the dc voltage source V_1. First and second diodes D_{1A} and D_{2A} are connected in antiparallel relation to the first and second switching transistors Q_1 and Q_2, respectively. Included in the circuit is a diode network composed of a series combination of diodes D_{11} and D_{12} and another series combination of diodes D_{21} and D_{22}. These series combinations are connected in parallel with one another between the first and second switching transistors Q_1 and Q_2. Another first diode D_{1B} is connected in series with diode D_{21} in antiparallel relation to the first switching transistor Q_1. Likewise, another second diode D_{2B} is connected in series with diode D_{22} in antiparallel relation to the second switching transistor Q_2. A series circuit of a first inductor L_1 and the parallel combination of discharge lamp **10** and bypass capacitor C_1 is connected between the output ends of the half-bridge or between the connection of diodes D_{11} and D_{12} and the connection of capacitors C_3 and C_4. Also included in the circuit is the transformer **T** with its secondary winging L_{22} connected in series with the discharge lamp **10** in parallel with the bypass capacitor C_1 and with its primary winding L_{21} connected in parallel with a capacitor C_5. The parallel combination of the primary winding L_{21} and capacitor C_5 is connected in series with a second inductor L_3 and a blocking capacitor C_2 between the connection of capacitors C_3 and C_4 and the connection of diodes D_{21} and D_{22}. In the above circuit, the capacitors C_3 and C_4 are charged from the dc voltage V_1 and in return supplies to the discharge lamp **10** the like composite lamp driving current of FIG. 5 as the first and second switching transistors Q_1 and Q_2 are driven in accordance with a timing diagram of FIG. 20.

In the chopper mode effected during the period T_{DC} (t_1 - t_2 and t_3 - t_4 in FIG. 20), one of the first and second switching transistors Q_1 and Q_2 is driven to turn on and off at a first high frequency while the other switching transistor is kept turned off, in order to provide across the output ends of the half-bridge the chopped voltage from one of the corresponding capacitors C_3 and C_4. The chopped voltage is smoothed by the first inductor L_1 and has its high frequency component routed through the bypass capacitor C_1, whereby applying the resulting smoothed dc current to the discharge lamp **10**. Such smoothed dc current has the polarity which is reversed from the period of t_1 - t_2 to the period of t_3 to t_4. The above chopper operation can be explained in terms of the following repeated sequence. For example, in the period T_{DC} of t_1 - t_2, when the first transistor Q_1 is on while the second switching transistor Q_2 is off, the capacitor C_3 supplies a current which flows through first switching transistor Q_1, diode D_{11}, first inductor L_1, discharge lamp **10**, secondary winding L_{22}, bypass capacitor C_1, and back to the capacitor C_3. Upon

the subsequent turning off of the first switching transistor Q_1, the first inductor L_1 acts to maintain the continuous flow of the current through the discharge lamp **10**, secondary winding L_{22}, bypass capacitor C_1, capacitor C_4, diode D_{2A}, and back to the first inductor L_1. During the period T_{DC} of t_3 - t_4, upon the turning on of the second switching transistor Q_2, the capacitor C_4 supplies a current which flows through secondary winding L_{22}, discharge lamp **10**, bypass capacitor C_1, first inguctor L_1, diode D_{12}, second switching transistor Q_2, and back to capacitor C_4. Upon the subsequent turning off of the second switching transistor Q_2, the first inductor L_1 causes the current to continuously flow therefrom and through diode D_{1A}, capacitor C_3, secondary winding L_{22}, discharge lamp **10**, and back to the first inductor L_1. With the provision of the half-bridge configuration, the loag circuit including the discharge lamp **10** receive one-half of the voltage of the dc voltage source.

For successfully bypassing the high frequency component of the chopped voltage through the bypass capacitor C_1 without causing an unstable lamp operation and at the same time without requiring the capacitor C_1 and the secondary winding L_{22} to become bulky, the first high frequency, the inductance of the first inductor L_1, and the capacitance C_1 of the bypass capacitor C_1 may be selected such that the combined impedance of the lamp **10** and the secondary winding L_{22} is to be **3** to **10** times that of the bypass capacitor C_1.

In the inverter mode during the period T_{HF} (t_2 - t_3 and t_4 - t_5), the first and second switching transistors Q_1 and Q_2 are controlled to alternately turn on and off with a dead-time therebetween at a second high frequency to provide a high frequency alternating current to the discharge lamp **10** as repeating the following four occurrences 1) to 4). At the first occurrence 1), for example, as indicated in the period of t_2 - t_3 in FIG. 20 in which the second switching transistor Q_2 is turned on while the first switching transistor Q_1 is off, the capacitor C_4 is cooperative with blocking capacitor C_2 to flow a current mainly through primary winding L_{21}, capacitor C_5, second inductor L_3, blocking capacitor C_2, diode D_{22}, second switching transistor Q_2, and back to capacitor C_4. At the second occurrence 2) in which both of the first and second switching transistors Q_1 and Q_2 are simultaneously off, the second inductor L_3 is cooperative with the primary winding L_{21} to release the accumulated energy to continuously flow the current mainly through blocking capacitor C_2, diode D_{1B}, capacitor C_3, primary winding L_{21}, capacitor C_5, and back to the second inductor L_3. At the third occurrence 3) in which the first switching transistor Q_1 is on while the second switching transistor Q_2 is off, the capacitor C_3 is cooperative with the blocking capacitor C_2 to flow a current in the opposite direction mainly through first switching transistor Q_1, diode D_{21}, blocking capacitor C_2, second inductor L_3, primary winding L_{21}, capacitor C_5, and back to the capacitor C_3. At the fourth occurrence 4) in which both of the first and second switching transistors Q_1 and Q_2 are off, the second inductor L_3 is cooperative with the primary winding L_{21} to maintain the continuous flow of the current mainly through primary winding L_{21}, capacitor C_5, capacitor C_4, diode D_{2B}, blocking capacitor C_2, and back to the second inguctor L_3.

In this connection, the diodes D_{1B} and D_{2B}, which are connected in antiparallel relation respectively to the first and second switching transistors Q_1 and Q_2, provide first and second bypass routes for continuously flowing the instantaneous currents released from the second inductor L_3 and the primary winding L_{21} at the second and fourth occurrences in which both of the switching transistors Q_1 and Q_2 are off.

Likewise, in the next second period of time T_{HF} (t_4 - t_5) which is initiated by turning on and off the first switching transistor Q_1 which has been active in the previous first time of period T_{DC}, the first and second switching transistors Q_1 and Q_2 are controlled to alternately turn on and off to produce the high alternating current through the primary winding L_{21}.

In this manner, during each second period of time T_{HF}, the high frequency alternating current continues to flow the primary winding L_{21} to thereby induce at the secondary winding L_{22} the corresponding high frequency alternating current which circulates through the closed loop of the secondary winding L_{22}, discharge lamp **10**, and bypass capacitor C_1 as the inductor L_1 blocks such high frequency alternating current, whereby driving the discharge lamp **10** by thus obtained high frequency alternating current.

It should be noted at this point that during the above inverter mode the first and second switching transistors Q_1 and Q_2 are driven at the second high frequency which is higher than the first high frequency at which they are driven in the above chopper mode, such that the first inductor L_1 block the second high frequency to thereby allow only a minute current to divert into the circuit of first inductor L_1 and capacitor C_1. It should be also noted that, during the chopper mode, the above diode network of diodes D_{11}, D_{12}, D_{21}, and D_{22} acts to prevent the current from diverting into the inverter circuit of blocking capacitor C_2, second inductor L_3, and primary winding L_{21} since the diode network acts to maintain the voltage of the blocking capacitor C_2 once it is charged up to one-half of the voltage of the dc voltage source V_1.

To explain the diode network operation in detail with reference to the occurrences during the chopper operation T_{DC}, diodes D_{12} and D_{21} are cooperative to block the current from diverting into the inverter circuit when the first switching transistor Q_1 is on while the second transistor is off; diodes D_{11}, D_{12}, D_{21}, and D_{22} are cooperative to block the same when both of the first and second switching transistors are off; and diodes D_{11} and D_{22} are cooperative to block the same when the second switching transistor Q_2 is on while the first switching transistor Q_1 is off.

With this arrangement of blocking the current from diverting into the inverter circuit during the chopper operation T_{DC}, no substantial alternating current is induced at the secondary winging L_{22} to thereby keep the smoothed dc current free from any ripple which would otherwise be superimposed thereupon in the absence of the diode network and would certainly result in unstable lamp operation.

In this embodiment, the discharge lamp **10** may be ignited with the addition of an L-C resonant starter circuit for inducing an increased ignition voltage across the secondary winging L_{22} while providing the high frequency alternating current to the discharge lamp **10** by the operation of the inverter. It is also effective to utilize a pulse-width-modulation technique for controlling the output of the circuit while monitoring the condition of the lamp **10** by means of the lamp current or the lamp voltage.

The period T_{HF} of the high frequency alternating current within one cycle (T_{HF} + T_{DC}) of the composite lamp driving current may differ from differing discharge lamps utilized, but is found, for example, for a typical 80 W mercury-arc lamp having a rated lamp voltage of 115 V, to be preferably less than 20 % of the one cycle in order to prevent the acoustic resonance and assure a stable lamp operation. In this instance, the one cycle (T_{HF} + T_{DC}) is preferably between several milliseconds and several tens of microseconds for the purpose of restraining flicker and noises.

The first and second switching frequencies can be suitably selected in relation to the inductances and capacitances of the circuit. For example, when first inguctor L_1, the bypass capacitor C_1, second inductor L_3, blocking capacitor C_2, capacitor C_5 are selected to have respective values that L_1 = 0.2 mH, C_1 = 0.1 µF, L_3 = 0.2 mH, C_2 = 0.15 µF, and C_5 = 0.033 µF for driving the above mercury-arc lamp with the dc voltage source V_1 of 280 V, the first and second switching transistors Q_1 and Q_2 are operated respectively at 40 KHz during the period T_{DC} and respectively at 80 KHz during the period T_{HF} for providing the composite lamp driving current as indicated in FIG. 5.

Seventh embodiment ⟨FIG. 21⟩

A seventh embodiment of the present invention has the similar circuit arrangement to that of the sixth embodiment except that the chopping operation is effected only by the first transistor Q_1. That is, in the chopper mode, only the first switching transistor Q_1 is driven to turn on and off, while in the inverter mode, both of the first and second switching transistors Q_1 and Q_2 are driven to operate in the same manner as in the sixth embodiment, thus providing the composite lamp driving current as seen in FIG. 16 The like diode network composed of diodes D_{11}, D_{12}, D_{21}, and D_{22} is also included to prevent the diversion of the undesired current between the series circuit of first inductor L_1, discharge lamp **10**, bypass capacitor C_1, and secondary winding L_{22}, and the inverter circuit of blocking capacitor C_2, second inductor L_3, and primary winging L_{21}.

Eighth embodiment ⟨FIGS. 22 and 23⟩

Referring now to FIG. 22, an eighth embodiment of the present invention is shown to comprise first and second switching transistors Q_1 and Q_2 connected in series across a dc voltage source V_1 with first and second diodes D_1 and D_2 connected in antiparallel relation to the first and second switching transistors Q_1 and Q_2, respectively. The first and second switching transistors Q_1 and Q_2 are coupled with capacitors C_3 and C_4 in a half-bridge configuration of which input ends are connected to the dc voltage source V_1. Connected between the output ends of the half-bridge is a series circuit of an inductor L_1 and a parallel combination of a discharge lamp **10** and a bypass capacitor C_1. The first and second switching transistors Q_1 and Q_2 are controlled in accordance with a timing chart of FIG. 23 to provide the like composite lamp driving current as shown in FIG. 5, as repeating the chopper and inverter functions.

In the chopper mode defined within the period T_{DC} (t_1 - t_2, t_3 - t_4) of FIG. 23, one of the first and second switching transistors Q_1 and Q_2 is driven to turn on and off at a first high frequency while the other switching transistor is kept turned off in order to provide a chopped voltage supplied from the corresponding one of the capacitors C_3 and C_4. The chopped voltage is then smoothed by the inductor L_1 and of which high frequency component is bypass through the bypass capacitor C_1, thus providing the resulting smoothed dc current to the discharge lamp **10**. As apparent from FIG. 23, the first and second switching transistors Q_1 and Q_2 are alternately made active from one cycle to the subsequent cycle to thereby reverse the polarity of the dc current applied to the discharge lamp

10 in a repeated manner. Such polarity reversal is not essential and therefore only one of the switching transistors Q_1 and Q_2 may be made active in the chopper mode of providing the dc current.

In the inverter mode defined within the period T_{HF} (t_2 -t_3, t_4 - t_5), the first and second switching transistors Q_1 and Q_2 are driven to alternately turn on and off with a dead-time therebetween at a second high frequency which is lower than the first high frequency, such that the discharge lamp **10** receives a resulting high frequency alternating current as the circuit repeats the following four occurrences 1) to 4), as indicated in FIG. 23. At the first occurrence 1) in which the first switching transistor Q_1 is off and the second switching transistor Q_2 is on, the capacitor C_4 discharges and causes a current to flow therefrom mainly through the discharge lamp **10**, inductor L_1, second switching transistor Q_2, and back to the capacitor Q_4. At the second occurrences 2) in which the first and second switching transistors Q_1 and Q_2 are simultaneously off, the inductor L_1 acts to continuously flow the current therefrom mainly through diode D_1, capacitor C_3, discharge lamp **10**, and back to the inductor L_1. At the third occurrence 3) in which the first switching transistor Q_1 is on while second switching transistor Q_2 is off, the capacitor C_3 discharges and causes a current to flow therefrom in the opposite direction through first switching transistor Q_1, inductor L_1, discharge lamp **10**, and back to the capacitor C_3. At the fourth occurrence 4) when first and second switching transistors Q_1 and Q_2 are simultaneously off, the inductor L_1 act to maintain the continuous flow of the current therefrom through discharge lamp **10**, capacitor C_4, diode D_2, and back to the inductor L_1.

In the above circuit, the inductance of L_1 is selected to have such a value that the second high frequency of the inverter operation will not be lowered to audio frequency. In this connection, the first high frequency of the chopper operation is selected to be higher than the second high frequency by such an extent as to increase the impedance of the inductor L_1 which limits the current flowing through the discharge lamp **10**.

Typical values for the components of the above circuit are, for instance, that C_1 = 0.7 µF, L_1 = 0.1 mH when V_1 = 140 V and that Q_1 and Q_2 are driven to operate at 100 KHz the chopper mode and at 30 KHz in the inverter mode.

Ninth embodiment ⟨FIG. 24⟩

A ninth embodiment of the present invention utilizes a dc voltage source comprising a diode bridge **DB** connected to an ac voltage source V_{AC} through a filtering circuit **FT**. The lamp driving circuit of the present embodiment is similar to that of the eighth embodiment except that the output of the dc voltage source **DB** is connected across the first switching transistor Q_1 through a second inductor L_2. Thus, in the chopper mode, only the first switching transistor Q_1 is driven to turn on and off in order to provide the smoothed dc current to the discharge lamp **10** in the manner as described with reference to the eighth embodiment. The inverter operation of the circuit is identical to that of the eighth embodiment. In this sense the first switching transistor Q_1 is commonly utilized both in the chopper and inverter modes. The characterizing feature of the present embodiment resides in that, in the chopper mode, the first switching transistor Q_1 is cooperative with the second inductor L_2 and diode D_2 to act as a positive booster for increasing the magnitude of the voltage acting to the series circuit of capacitors C_3 and C_4. That is, the energy accumulated in the second inductor L_2 during the chopping operation is additive to the dc power source **DB** to apply the resultant added voltage to the capacitors C_3 and C_4 for charging the same at the high frequency up to the voltage higher than that of the ac voltage source V_{AC}. Also with this result, the input current I_{AC} can take the form of a sine wave, thereby making it possible to have an improved power factor of more than 90 %.

Tenth embodiment ⟨FIGS. 25 and 26⟩

A tenth embodiment of the present invention is similar to the eighth embodiment except that another pair of switching transistors Q_3 and Q_4 is incorporated as replacing the pair of capacitors C_3 and C_4 to form a full-bridge configuration with diodes D_3 and D_4 connected in antiparallel relation to the switching transistors Q_3 and Q_4. These four switching transistors Q_1 to Q_4 are driven in accordance with a timing chart of FIG. 26 to provide the like composite lamp driving current as shown in FIG. 5.

In the chopper mode defined within the period of T_{DC} (t_1 -t_2) during which the second and third switching transistors Q_2 and Q_3 are off, the first switching transistor Q_1 is turned on and off at a first high frequency while the fourth switching transistor Q_4 is kept turned on in order to provide from the dc voltage V_1 a chopped voltage which is smoothed by the inductor L_1 and of which high frequency component is bypassed through the bypass capacitor C_1, thereby providing to the discharge lamp **10** the smoothed dc voltage. Also in the chopper mode defined within the period of T_{DC} (t_3 - t_4) during which the first and fourth switching transistor Q_1 and Q_4 is off, the third switching transislor Q_3 is driven to turn on and off at the first frequency while the second switching transistor Q_2 is kept turned on, thereby providing the smoothed

dc voltage of the opposite polarity in the like manner as above.

In the inverter mode defined within the period T_{HF} (t_2 -t_3), the first and fourth switching transistors Q_1 and Q_4 are driven to turn on and off at a second high frequency, which is lower than the first high frequency, in synchronism with one another and in an alternate manner with the second and third switching transistors Q_2 and Q_3 turning on and off in synchronism with one another, thus providing the resulting high frequency alternating current to the discharge lamp **10** the high frequency alternating current. In the inverter mode defined within the period T_{HF} (t_4 - t_5), these four transistors Q_1 to Q_4 are operated in the opposite manner to provide the like high frequency alternating current to the discharge lamp **10**. The second frequency, at which the switching transistors Q_1 to Q_4 are operated to provide the high frequency alternating current during the period T_{HF} (t_2 - t_3 and t_4 - t_5), is selected such as to cause a resonance in the series circuit of bypass capacitor C_1 and inductor L_1, enabling to apply a high voltage sufficient to operate the discharge lamp stably. Typical values for the components of the above circuit are, for instance, that C_1 = 0.7 μF, L_1 = 0.1 mH when V_1 = 140 V and that Q_1 and Q_2 are driven to operate at 100 KHz in the chopper mode and at 30 KHz in the inverter mode.

Modification of tenth embodiment (FIG. 27)

The circuit of FIG. 25 of the tenth embodiment may be operated in accordance with a timing chart of FIG. 27 for providing the like composite lamp driving current to the discharge lamp. In this modification which is identical to the tenth embodiment except for the switching operation in the chopper mode. That is, during the period T_{DC} (t_1 - t_2), the first and fourth switching transistors Q_1 and Q_4 are driven to simultaneously turn on and off, and during the period T_{DC} (t_3 - t_4) the second and third switching transistors Q_2 and Q_3 are driven to simultaneously turn on and off. With this result, upon the simultaneous off of the paired transistors, the energy stored in the inductor L_1 in the previous turning on of the switching transistors is allowed to flow back to the dc voltage V_1 through the corresponding two of the diodes D_1 to D_4. For example, when the switching transistors Q_1 and Q_4 are simultaneously off after being turned on during the period T_{DC} of t_1 - t_2, the inductor L_1 causes an instantaneous current to flow therefrom through diode D_3, dc voltage source V_1, diode D_2, discharge lamp **10**, and back to the inductor L_1. And when the second and third switching transistors Q_2 and Q_3 are off after being turned on, the inductor L_1 acts to maintain the continuous flow of an instantaneous current in opposite direction therefrom through discharge lamp **10** and bypass capacitor C_1, diode D_1, dc voltage source V_1, diode D_4 and back to the inductor L_1.

LIST OF REFERENCE NUMERALS

10
discharge lamp
V_1
dc voltage source
Q_1 - Q_4
switching transistors
C_1
bypass capacitor
C_2
blocking capacitor
C_3 - C_5
capacitor
L_1, L_3
inductor
T
transformer
L_{21}
primary winding
L_{22}
secondary winding
Ia
lamp current
D_1 - D_4
diode
D_{11}, D_{12}, D_{21}, D_{22}
diode
D_{1A}, D_{1B}, D_{2A}, D_{2B}
diode
V_{AC}
ac voltage source
FT
filter circuit
DB
diode bridge
CH
chopper
IV
inverter

Claims

1. A discharge lamp driving circuit comprising:
a dc (direct current) voltage source;
chopper means comprising a first switching circuit which is coupled to said dc voltage source to provide therefrom a periodically interrupted current and smooth the same for producing a smoothed dc current;
inverter means comprising a second switching circuit which is coupled to said dc voltage source for producing therefrom a high

frequency alternating current;

control means connected to said chopper means and said inverter means to apply to said discharge lamp a repeating cycle of a composite lamp driving current composed of said high frequency alternating current interrupted by said smoothed dc current; characterised by

said chopper means and said inverter means having in their first and second switching circuits at least one common switching element.

2. A discharge lamp driving circuit as set forth in claim 1,

wherein said chopper means is configured to apply said smoothed dc current while reversing the polarity thereof from one cycle to the subsequent cycle of said composite lamp driving current.

3. A discharge lamp driving circuit as set forth in claim 1,

wherein the first switching circuit of said chopper means comprises said at least one common switching element (Q_1,Q_2) which is coupled in series circuit with an inductor (L_1), said dc voltage source (V_1), and a parallel combination of said discharge lamp (10) and a bypass capacitor (C_1),

said switching element being driven to turn on and off at a first high frequency during a first period of time to produce said interrupted current which is smoothed by said first inductor (L_1) and is removed of its high frequency component by said bypass capacitor (C_1) in order to apply said smoothed dc current to said discharge lamp (10) within each cycle of said composite lamp driving current;

the second switching circuit of said inverter means comprising a pair of first and second switching elements (Q_1,Q_2) at least one of which is common to said first switching circuit, said first and second switching elements being connected in circuit with a dc blocking capacitor (C_2) and a transformer (T) with a primary winding (L_{21}) and a secondary winding (L_{22}) which is inserted in series relation with said discharge lamp and in parallel relation with said bypass capacitor (C_1);

said first and second switching elements (Q_1,Q_2) being connected in series circuit across said dc voltage source with the series circuit of said dc blocking capacitor (C_2) and the primary winding (L_{21}) being connected across one of said first and second switching elements (Q_1,Q_2) to form therewith a series oscillating circuit;

said first and second switching elements (Q_1,Q_2) being controlled to alternately turn on and off at a second high frequency during a second period of time alternating with said first period of time in order to provide a high frequency alternating current at said series oscillating circuit as repeating to charge and discharge said dc blocking capacitor (C_2), whereby inducing said high frequency alternating current in the circuit of said secondary winding (L_{22}) and said discharge lamp (10) to provide said high frequency alternating current to said discharge lamp (10) within each cycle of said composite lamp driving current.

4. A discharge lamp driving circuit as set forth in claim 1, wherein said first switching circuit of said chopper means comprises a single pair of first and second chopper switching elements (Q_1,Q_2) and a pair of first and second capacitors (C_3,C_4) arranged in a half bridge configuration having its input ends connected across said dc voltage source and having its output ends connected across a series circuit of an inductor (L_1) and a parallel combination of said discharge lamp (10) and a bypass capacitor (C_1);

one of said first and second chopper switching elements (Q_1,Q_2) being controlled to repetitively turn on and off at a first high frequency while the other switching element is kept turned off during a first period of time in order to provide to said discharge lamp within each cycle of said composite lamp driving current the dc current which is smoothed by said inductor (L_1) and is removed of its high frequency component by said bypass capacitor (C_1), said first and second chopper switching elements (Q_1,Q_2) being controlled to alternately turn off at said first high frequency with one of them being driven to repetitively turn on and off so as to change the polarity of said smoothed dc current applied to said discharge lamp (10) from one cycle to the subsequent cycle of said composite lamp driving current;

said second switching circuit of said inverter means comprising a pair of first and second inverter switching elements (Q_2,Q_3) at least one of which is common to said first switching circuit, said first and second switching elements being connected in circuit with a dc blocking capacitor (C_2) and a transformer (T) with a primary winding (L_{21}) and a secondary winding (L_{22}) which is inserted in series relation with said discharge lamp (10) and in parallel relation with said bypass capacitor (C_1);

said first and second chopper switching elements (Q_1,Q_2) being connected in series circuit across said dc voltage source with the series circuit of said dc blocking capacitor (C_2) and the primary winding (L_{21}) being connected across one of said first and second chopper switching elements to form therewith a series oscillating circuit;

said first and second inverter switching elements being controlled to alternately turn on and off at a second high frequency during a second period of time alternating with said first period of time in order to provide a high frequency alternating current at said series oscillating circuit as repeating to charge and discharge said dc blocking capacitor (C_2), whereby inducing said high frequency alternating current in the circuit of said secondary winding (L_{22}) and said discharge lamp (10) to provide said high frequency alternating current to said discharge lamp within each cycle of said composite lamp driving current.

5. A discharge lamp driving circuit as set forth in claim 4,

wherein said oscillating circuit includes first and second diodes (D_1,D_2);

said first diode (D_1) connected across said first switching element (Q_1) in antiparallel relation therewith to form a first bypass route for a first instantaneous current which is discharged from said primary winding (L_{21}) immediately after the simultaneous turning off of said first and second switching elements (Q_1,Q_2) occurring after said first and second switching elements being simultaneously turned off and on, respectively, whereby allowing said first instantaneous current to continuously flow through said oscillating circuit in one direction through said first bypass route;

said second diode (D_2) being connected across said second switching element (Q_2) in antiparallel relation therewith to form a second bypass route for a second instantaneous current which is discharged from said primary winding (L_{21}) immediately after the simultaneous turning off of said first and second switching elements occurring after said first and second switching elements (Q_1,Q_2) being simultaneously turned on and off respectively, whereby allowing said second instantaneous current to continuously flow through said oscillating circuit in the opposite direction through said second bypass route.

6. A discharge lamp driving circuit as set forth in claim 5,

further including a diode network connected in circuit between said first switching circuit of said chopper means and said second switching circuit of said inverter means in such a manner as to prevent said dc blocking capacitor (C_2) from repeating to be charged and discharges during the first period of time .

7. A discharge lamp driving circuit as set forth in claim 1,

wherein said first and second switching circuits commonly includes a pair of first and second switching elements (Q_1,Q_2) arranged in a bridge configuration having its input ends connected across said dc voltage source and having its output ends connected across a series circuit of an inductor (L_1) and a parallel combination of said discharge lamp (10) and a bypass capacitor (C_1);

one of said first and second switching elements (Q_1,Q_2) being controlled to turn on and off at a first frequency with the other switching element (Q_2) being kept turned off during a first period of time to provide to said series circuit a dc current which is smoothed by said inductor (L_1) and is removed of its high frequency component by said bypass capacitor (C_1) for feeding said smoothed dc current to said discharge lamp within each cycle of said composite lamp driving current;

said first and second switching elements (Q_1,Q_2) being controlled to alternately turn on and off during a second period of time alternating with said first period of time in such a manner as to provide to said discharge lamp said high frequency alternating current with a second high frequency within each cycle of said composite lamp driving current.

8. A discharge lamp driving circuit as set forth in claim 7,

wherein said second high frequency is lower than said first high frequency at which said switching elements (Q_1,Q_2) are turned on and off for producing said smoothed dc current so that said high frequency alternating current at said second frequency is allowed to be substantially fed to said discharge lamp (10).

9. A discharge lamp driving circuit as set forth in claim 1,

wherein said first switching circuit of said chopper means comprises a pair of first and second switching elements (Q_1,Q_2) and a pair of first and second capacitors (C_3,C_4) which are arranged in a half-bridge configuration having its input ends connected across said dc voltage source and having its output ends connected across a series circuit of an inductor

(L_1) and a parallel combination of said discharge lamp (10) and a bypass capacitor (C_1);

each one of said first and second switching elements (Q_1,Q_2) being controlled to turn on and off at a first high frequency with the other switching element being kept turned off during a first period of time to provide to said series circuit a dc current which is smoothed by said inductor (L_1) and is removed of its high frequency component by said bypass capacitor (C_1) in order to provide said smoothed dc current to said discharge lamp (10) while reversing the polarity thereof from one cycle to the subsequent cycle of said composite lamp driving current;

said first and second switching elements (Q_1,Q_2) being controlled to turn on and off during a second period of time alternating with said first period of time to provide said high frequency alternating current with a second high frequency to said series circuit of said inductor (L_1) and the parallel combination of said discharge lamp (10) and said bypass capacitor (C_1);

said second high frequency being lower than said first high frequency to such an extent that said second high frequency alternating current is supplied to said discharge lamp (10) within each cycle of said composite lamp driving current while allowing said second high frequency component to be fed substantially to said discharge lamp without being substantially bypassed through said bypass capacitor (C_1).

Patentansprüche

1. Entladungslampenbetriebsschaltung mit:
   - einer DC (Gleichstrom)-Spannungsquelle;
   - Zerhackermittel mit einem ersten Schaltkreis, der mit der Gleichspannungsquelle zur Erzeugung eines periodisch unterbrochenen Stromes aus dieser und zum Glätten des Stromes zur Erzeugung eines geglätteten Gleichstroms verbunden ist;
   - Invertermittel mit einem zweiten Schaltkreis, der mit der Gleichspannungsquelle zur Erzeugung eines hochfrequenten Wechselstroms aus dieser verbunden ist;
   - Kontrollmittel, die mit den Zerhackermitteln und den Invertermitteln verbunden sind, um auf die Entladungslampe einen sich wiederholenden Zyklus eines zusammengesetzten Lampenbetriebsstroms aufzubringen, der aus dem durch den geglätteten Gleichstrom unterbrochenen hochfrequenten Wechselstrom besteht; dadurch gekennzeichnet daß
   - die Zerhackermittel und die Invertermittel in ihrem ersten Schaltkreis und in ihrem zweiten Schaltkreis wenigstens ein gemeinsames Schaltelement aufweisen.

2. Entladungslampenbetriebsschaltung nach Anspruch 1,
   - wobei das Zerhackermittel dazu ausgebildet ist, den geglätteten Gleichstrom unter Umkehren der Polarität von einem Zyklus zu dem nachfolgenden Zyklus des zusammengesetzten Lampenbetriebsstroms aufzubringen.

3. Entladungslampenbetriebsschaltung nach Anspruch 1,
   - wobei der erste Schaltkreis des Zerhackermittels wenigstens ein gemeinsames Schaltelement (Q_1, Q_2) aufweist, das in einer Reihenschaltung mit einer Induktivität (L_1), der Gleichspannungsquelle (V_1) und einer Parallelkombination bestehend aus der Entladungslampe (10) und einer Überbrückungskapazität (C_1) gekoppelt ist,

     - - das Schaltelement betrieben wird, um mit einer ersten hohen Frequenz während einer ersten Zeitperiode ein- und auszuschalten, um einen unterbrochenen Strom zu erzeugen, der von der ersten Induktivität (L_1) geglättet ist und dessen hochfrequente Komponente durch die Überbrückungskapazität (C_1) entfernt ist, um den geglätteten Gleichstrom auf die Entladungslampe (10) bei jedem Zyklus des zusammengesetzten Lampenbetriebsstroms aufzubringen.

     - - der zweite Schaltkreis der Invertermittel ein Paar von ersten und zweiten Schaltelementen (Q_1, Q_2) aufweist, von denen wenigstens eines auch dem ersten Schaltkreis zugehörig ist, wobei erste und zweite Schaltelemte in der Schaltung mit einer die Gleichspannung blockierenden Kapazität (C_2) und einen Transformator T mit einer Primärwicklung (L_{21}) und einer Sekundärwicklung (L_{22}), die in Reihe mit der Entladungslampe und parallel zu der Überbrükkungs-Kapazität (C_1) geschaltet ist, verbunden sind;

     - - das erste Schaltelement (Q_1) und das zweite Schaltelement (Q_2) in Reihenschaltung über die Gleichspannungsquelle geschaltet sind, wobei die Reihenschaltung bestehend aus der die Gleichspannung blockenden Kapazität (C_2) und der Primärwicklung (L_{21}) über das erste

Schaltelement (Q_1) oder das zweite Schaltelement (Q_2) verbunden ist, um mit diesem einen Reihenschwingkreis zu bilden;

- - das erste Schaltelement (Q_1) und das zweite Schaltelement (Q_2) gesteuert werden, um mit einer zweiten hohen Frequenz während einer zweiten Zeitdauer, die mit der ersten Zeitdauer abwechselt alternierend ein- und auszuschalten, um einen hochfrequenten Wechselstrom an dem Reihenschwingkreis zu erzeugen, so daß die die Gleichspannung blockende Kapazität (C_2) wiederholt geladen und entladen wird, wodurch der hochfrequente Wechselstrom in die Schaltung bestehend aus der Sekundärwicklung (L_{22}) und der Entladungslampe (10) induziert wird, um den hochfrequenten Wechselstrom der Entladungslampe (10) in jedem Zyklus des zusammengesetzten Lampenbetriebsstroms zu führen.

4. Entladungslampenbetriebsschaltung nach Anspruch 1,
   - wobei der erste Schaltkreis der Zerhackermittel ein einziges Paar bestehend aus einem ersten Zerhackerschaltelement (Q_1) und einem zweiten Zerhackerschaltelement (Q_2) und einem Paar bestehend aus einer ersten Kapazität (C_3) und einer zweiten Kapazität (C_4), die in einer Halbbrückenausbildung angeordnet sind, deren Eingangsanschlüsse über die Gleichspannungsquelle verbunden sind und deren Ausgangsenden über eine Reihenschaltung bestehend aus einer Induktivität (L_1) und einer Parallelkombination der Entladungslampe (10) und einer Überbrückungskapazität (C_1) verbunden sind, aufweist,
   - entweder das erste Zerhackerschaltelement (Q_1) oder das zweite Zerhackerschaltelement (Q_2) gesteuert wird, um mit einer ersten hohen Frequenz wiederholend ein- und auszuschalten, während das andere Schaltelement während einer ersten Zeitdauer ausgeschaltet bleibt, um die Entladungslampe während jedes Zyklus des zusammengesetzten Lampenbetriebsstroms mit einem Gleichstrom zu versorgen, der von der Induktivität (L_1) geglättet ist und von dem die Hochfrequenzkomponente durch die Überbrükkungskapazität (C_1) entfernt ist, das erste Zerhackerschaltelement (Q_1) und das zweite Zerhackerschaltelement (Q_2) gesteuert werden, um alternierend ausgeschaltet werden, wobei das eine von ihnen betrieben ist, um wiederholt ein- und auszuschalten wird, um so die Polarität des auf die Entladungslampe (10) von einem Zyklus zu dem nachfolgenden Zyklus des zusammengesetzten Lampenbetriebsstroms aufgebrachten geglätteten Gleichstroms zu ändern,
   - der zweite Schaltkreis der Invertermittel ein Paar von ersten Inverterschaltelementen (Q_2) und zweiten Inverterschaltelementen (Q_3), von denen wenigstens eines mit dem ersten Schaltkreis gemeinsam ist, aufweist, wobei das erste und das zweite Schaltelement im Schaltkreis mit einer Gleichspannungs-Blockkapazität (C_2) verbunden sind und einen Transformator (T) mit einer Primärwicklung (L_{21}) und einer Sekundärwicklung (L_{22}) die in Reihe mit der Entladungslampe (10) und parallel mit der Überbrückungskapazität (C_1) geschaltet ist, aufweisen;

     - - das erste Zerhackerschaltelement (Q_1) und das zweite Zerhackerschaltelement (Q_2) in Reihe über der Gleichspannungsquelle mit der Reihenschaltung bestehend aus der Gleichspannungs-Blockkapazität (C_2) und der Primärwicklung (L_{21}) über das erste oder das zweite Zerhackerschaltelement geschaltet sind, um mit diesem einen Reihenschwingkreis zu bilden;

     - - das erste und das zweite Inverterschaltelement gesteuert werden, um mit einer zweiten hohen Frequenz während eines zweiten Zeitraums, der mit dem ersten Zeitraum abwechselt, alternierend ein- und auszuschalten, um einen hochfrequenten Wechselstrom an dem Reihenschwingkreis zu erzeugen, so daß eine Ladung und Entladung der Gleichspannungs-Blockkapazität (C_2) wiederholt entsteht, wodurch ein hochfrequenter Wechselstrom in dem Schaltkreis bestehend aus der Sekundärwicklung (L_{22}) und der Entladungslampe (10) induziert wird, um den hochfrequenten Wechselstrom bei jedem Zyklus des zusammengesetzten Lampenbetriebsstroms an die Entladungslampe anzulegen.

5. Entladungslampenbetriebsschaltung nach Anspruch 1, wobei der Schwingkreis erste und zweite Dioden (D_1, D_2) aufweist;
   - die erste Diode (D_1) über dem ersten Schaltelement (Q_1) antiparallel zu diesem geschaltet ist, um einen Überbrückungsweg für einen ersten auftretenden Strom

zu schaffen, der von der Primärwicklung (L_{21}) entladen wird unmittelbar nach dem gleichzeitigen Ausschalten des ersten und des zweiten Schaltelements (Q_1, Q_2), der auftritt, nachdem das erste und das zweite Schaltelement gleichzeite aus- bzw. eingeschaltet worden sind, wodurch ein erster auftretender Strom kontinuierlich durch den Schwingkreis in einer Richtung durch den ersten Überbrükkungsweg fließen kann;

- die zweite Diode (D_2) über dem zweiten Schaltelement (Q_2) antiparallel mit dieser liegt, um einen zweiten Überbrückungsweg für einen zweiten auftretenden Strom zu schaffen, der von der Primärwicklung (L_{21}) unmittelbar nach dem gleichzeitigen Ausschalten des ersten und des zweiten Schaltelements entladen wird, auftretend nachdem das erste und das zweite Schaltelement (Q_1, Q_2) gleichzeitig ein- bzw. ausgeschaltet worden sind, wodurch ein zweiter auftretender Strom kontinuierlich durch den Schwingkreis in entgegengesetzter Richtung durch den zweiten Überbrückungsweg fließt.

6. Entladungslampenbetriebsschaltung nach Anspruch 5,
weiter mit einem Diodennetzwerk, das in einem Schaltkreis zwischen dem ersten Schaltkreis der Zerhackermittel und dem zweiten Schaltkreis der Invertermittel derart geschaltet ist, um ein wiederholtes Laden und Entladen der Gleichspannungs-Blockkapazität (C_2) während des ersten Zeitraums zu verhindern.

7. Entladungslampenschaltkreis nach Anspruch 1, wobei der erste und der zweite Schaltkreis gemeinsam ein Paar von ersten und zweiten Schaltelementen (Q_1, Q_2) aufweisen, die in einer Brückenschaltung angeordnet sind und deren Eingangsanschlüsse über die Gleichspannungsquelle verbunden sind und deren Ausgangsenden über eine Reihenschaltung bestehend aus einer Induktivität und einer Parallelkombination der Entladungslampe (10) und einer Überbrückungskapazität (C_1) verbunden sind;
   - das erste Schaltelement (Q_1) oder das zweite Schaltelement (Q_2) gesteuert wird, um mit einer ersten Frequenz ein- und auszuschalten, wobei das andere Schaltelement (Q_2) ausgeschaltet bleibt, während einer ersten Zeitdauer, um der Reihenschaltung einen Gleichstrom zuzuführen, der durch die Induktivität (L_1) geglättet ist und dessen Hochfrequenzkomponente von der Überbrückungskapazität (C_1) entfernt worden ist, um den geglätteten Gleichstrom zu der Entladungslampe bei jedem Zyklus des zusammengesetzten Lampenbetriebsstroms zuzuführen;
   - das erste Schaltelement (Q_1) und das zweite Schaltelement (Q_2) gesteuert sind, um alternierend während eines zweiten Zeitraums, der sich mit dem ersten Zeitraum abwechselt, ein- und auszuschalten, um so die Entladungslampe mit dem hochfrequenten Wechselstrom mit einer zweiten hohen Frequenz während jedes Zyklus des zusammengesetzten Lampenbetriebsstroms zu versorgen.

8. Entladungslampenbetriebsschaltung nach Anspruch 1,
wobei die zweite hohe Frequenz geringer ist als die erte hohe Frequenz, mit der die Schaltelemente (Q_1, Q_2) ein- und ausgeschaltet worden sind, um den geglätteten Gleichstrom zu erzeugen, so daß der hochfrequente Wechselstrom mit der zweiten Frequenz im wesentlichen zu der Entladungslampe (10) geführt werden kann.

9. Entladungslampenbetriebsschaltung nach Anspruch 1,
wobei der erste Schaltkreis der Zerhackermittel ein Paar von ersten und zweiten Schaltelementen (Q_1,Q_2) und ein Paar von ersten und zweiten Kapazitäten (C_3, C_4) aufweist, die in einer Halbbrückenschaltung angeordnet sind, deren Eingangsanschlüsse über die Gleichspannungsquelle verbunden sind und deren Ausgangsanschlüsse über eine Reihenschaltung bestehend aus einer Induktion und einer Parallelkombination bestehend aus der Entladungslampe (10) und einer Überbrückungskapazität (C_1) geschaltet sind;
   - sowohl das erste als auch das zweite Schaltelement (Q_1, Q_2) gesteuert wird, um mit einer ersten hohen Frequenz einund auszuschalten, wobei das andere Schaltelement ausgeschaltet bleibt, während einer ersten Zeitperiode, um die Reihenschaltung mit einem Gleichstrom zu versorgen, der von der Induktivität (L_1) geglättet ist und dessen Hochfrequenzkomponente von der Überbrükkungskapazität (C_1) entfernt ist, um den geglätteten Gleichstrom für die Entladungslampe (10) zu schaffen, während deren Polarität von einem Zyklus zu dem nachfolgenden Zyklus des zusammenge-

setzten Lampenbetriebsstrom umgekehrt wird;

- das erste Schaltelement (Q_1) und das zweite Schaltelement (Q_2) gesteuert werden, um während eines zweiten Zeitraums, der mit dem ersten Zeitraum alterniert, ein- und auszuschalten, um den hochfrequenten Wechselstrom mit einer Zweiten hohen Frequenz für die Reihensschaltung aus der Induktion (L_1) und der Parallelkombination aus der Entladungslampe (10) und der Überbrückungskapazität (C_1) zu schaffen;
- die zweite hohe Frequenz in einem solchen Maße geringer geringer als die erste hohe Frequenz ist, daß der zweite hochfrequente Wechselstrom bei jedem Zyklus des zusammengesetzten Lampenbetriebsstrom zu der Entladungslampe (10) geliefert wird, während zugelassen wird, daß die zweite hochfrequente Komponente im wesentlichen ohne erhebliche Überbrückung durch die Überbrückungskapazität (C_1) zu der Entladungslampe geführt wird.

Revendications

1. Circuit de commande de lampe à décharge, comprenant:

   une source de tension continue (courant continu);

   un moyen découpeur, comprenant un premier circuit de commutation qui est couplé à ladite source de tension continue pour produire, à partir de cette dernière, un courant périodiquement interrompu et le lisser pour produire un courant continu lissé;

   un moyen onduleur, comprenant un second circuit de commutation qui est couplé à ladite source de tension continue, pour produire, à partir de cette dernière, un courant alternatif à fréquence élevée;

   un moyen de commande relié audit moyen découpeur et audit moyen onduleur, pour appliquer à ladite lampe à décharge un cycle répété de courant composite de commande de lampe, constitué dudit courant alternatif à fréquence élevée interrompu par ledit courant continu lissé;

   caractérisé par le fait que :

   ledit moyen découpeur et ledit moyen onduleur présentent au moins un élément de commutation commun dans leurs premier et second circuits de commutation.

2. Circuit de commande de lampe à décharge selon la revendication 1, dans lequel ledit moyen découpeur est configuré pour appliquer ledit courant continu lissé, tout en inversant sa polarité d'un cycle au cycle suivant dudit courant composite de commande de lampe.

3. Circuit de commande de lampe à décharge selon la revendication 1, dans lequel le premier circuit de commutation dudit moyen découpeur comprend ledit au moins un élément de commutation commun (Q_1, Q_2), qui est un circuit couplé en série avec une bobine d'induction (L_1), ladite source de tension continue (V_1) et une combinaison parallèle de ladite lampe à décharge (10) et d'un condensateur de découplage (C_1),

   ledit élément de commutation étant commandé pour être passant et être bloqué à une première fréquence élevée, durant une première période de temps, pour produire ledit courant interrompu qui est lissé par ladite première bobine d'induction (L_1) et dont la composante à fréquence élevée est supprimée par ledit condensateur de découplage (C_1), en vue d'appliquer ledit courant continu lissé à ladite lampe à décharge (10), lors de chaque cycle dudit courant composite de commande de lampe,

   le second circuit de commutation dudit moyen onduleur comprenant un premier couple de premier et second éléments de commutation (Q_1, Q_2), dont au moins l'un est commun audit premier circuit de commutation, lesdits premier et second éléments de commutation étant reliés en circuit à un condensateur de blocage de courant continu (C_2) et un transformateur (T), comportant un enroulement primaire (L_{21}) et un enroulement secondaire (L_{22}), qui est inséré en série avec ladite lampe à décharge et en parallèle par rapport audit condensateur de découplage (C_1),

   lesdits premier et second éléments de commutation (Q_1, Q_2), reliés en série, étant reliés aux bornes de ladite source de tension continue, le circuit série formé dudit condensateur de blocage de courant continu (C_2) et de l'enroulement primaire (L_{21}) étant relié aux bornes de l'un desdits premier et second éléments de commutation (Q_1, Q_2), pour former avec lui un circuit oscillant série,

   lesdits premier et second éléments de commutation (Q_1, Q_2) étant commandés pour être alternativement passants et bloqués à une seconde fréquence élevée, durant une seconde période de temps, alternant avec ladite première période de temps, en vue de produire un courant alternatif à fréquence élevée sur ledit circuit oscillant série, de façon répétée pour charger et décharger ledit condensateur

de blocage de courant continu (C_2), de manière à induire ledit courant alternatif à fréquence élevée dans le circuit formé par ledit enroulement secondaire (L_{22}) et ladite lampe à décharge (10), pour fournir ledit courant alternatif à fréquence élevée à ladite lampe à décharge (10) lors de chaque cycle dudit courant composite de commande de lampe.

4. Circuit de commande de lampe à décharge selon la revendication 1, dans lequel ledit premier circuit de commutation dudit moyen découpeur comprend un seul couple de premier et second éléments de commutation de découpeur (Q_1, Q_2) et un couple de premier et second condensateurs (C_3, C_4), agencés selon une configuration en demi-pont dont les extrémités d'entrée sont reliées aux bornes de ladite source de tension continue et dont les extrémités de sortie sont reliées aux bornes d'un circuit série constitué d'une bobine d'induction (L_1) et d'une combinaison parallèle entre ladite lampe à décharge (10) et un condensateur de découplage (C_1),

l'un desdits premier et second éléments de commutation de découpeur (Q_1, Q_2) étant commandé pour être répétitivement passant et bloqué à une première fréquence élevée, tandis que l'autre élément de commutation reste bloqué durant une première période de temps, en vue de fournir à ladite lampe à décharge, lors de chaque cycle dudit courant composite de commande de lampe, le courant continu qui est lissé par ladite bobine d'induction (L_1) et dont la composante à fréquence élevée est supprimée par ledit condensateur de découplage (C_1), lesdits premier et second éléments de commutation de découpeur (Q_1, Q_2) étant commandés pour se bloquer alternativement à ladite première fréquence élevée, l'un d'entre eux étant commandé pour être alternativement passant et bloqué, de manière à faire varier la polarité dudit courant continu lissé appliqué à ladite lampe à décharge (10), d'un cycle au cycle suivant dudit courant composite de commande de lampe,

ledit second circuit de commutation dudit moyen onduleur comprenant un couple de premier et second éléments de commutation d'onduleur (Q_2, Q_3), dont au moins l'un est commun audit premier circuit de commutation, lesdits premier et second éléments de commutation étant reliés à un condensateur de blocage de courant continu (C_2) et à un transformateur (T), comportant un enroulement primaire (L_{21}) et un enroulement secondaire (L_{22}), qui est inséré en série avec ladite lampe à décharge (10) et en parallèle par rapport audit condensateur de découplage (C_1),

lesdits premier et second éléments de commutation de découpeur (Q_1, Q_2), reliés en série, étant reliés aux bornes de ladite source de tension continue, le circuit série formé dudit condensateur de blocage de courant continu (C_2) et ce l'enroulement primaire (L_{21}) étant relié aux bornes de l'un desdits premier et second éléments de commutation de découpeur, pour former avec lui un circuit oscillant série,

lesdits premier et second éléments de commutation d'onduleur étant commandés pour être alternativement passants et bloqués à une seconde fréquence élevée, durant une seconde période de temps alternant avec ladite première période de temps, en vue de produire un courant alternatif à fréquence élevée sur ledit circuit oscillant série, de façon répétée pour charger et décharger ledit condensateur de blocage de courant continu (C_2), de manière à induire ledit courant alternatif à fréquence élevée dans le circuit formé dudit enroulement secondaire (L_{22}) et de ladite lampe à décharge (10), pour fournir ledit courant alternatif à fréquence élevée à ladite lampe à décharge lors de chaque cycle dudit courant composite de commande de lampe.

5. Circuit de commande de lampe à décharge selon la revendication 4, dans lequel ledit circuit oscillant comprend des première et seconde diodes (D_1, D_2),

ladite première diode (D_1) étant reliée aux bornes dudit premier élément de commutation (Q_1), en antiparallèle sur lui, pour former un premier chemin de dérivation pour un premier courant instantané s'écoulant dudit enroulement primaire (L_{21}), immédiatement après le blocage simultané desdits premier et second éléments de commutation (Q_1, Q_2) se produisant après les mises simultanées aux états respectivement bloqué et passant desdits premier et second éléments de commutation, ce qui permet audit premier courant instantané de s'écouler de façon continue dans ledit circuit oscillant, dans une direction suivant ledit premier chemin de dérivation,

ladite seconde diode (D_2) étant reliée aux bornes dudit second élément de commutation (Q_2), en antiparallèle sur lui, pour former un second chemin de dérivation pour un second courant instantané s'écoulant dudit enroulement primaire (L_{21}), immédiatement après le blocage simultané desdits premier et second éléments de commutation se produisant après les mises simultanées aux états respectivement passant et bloqué desdits premier et

second éléments de commutation (Q1, Q2), ce qui permet audit second courant instantané de s'écouler de façon continue dans ledit circuit oscillant, dans la direction opposée suivant ledit second chemin de dérivation.

6. Circuit de commande de lampe à décharge selon la revendication 5, comprenant en outre un réseau de diodes branché entre ledit premier circuit de commutation dudit moyen découpeur et ledit second circuit de commutation dudit moyen onduleur de manière à empêcher ledit condensateur de blocage de courant continu (C_2) d'être répétitivement chargé et déchargé durant la première période de temps.

7. Circuit de commande de lampe à décharge selon la revendication 1, dans lequel lesdits premier et second circuits de commutation comprennent en commun un couple de premier et second éléments de commutation (Q_1, Q_2) agencé selon une configuration de pont dont les extrémités d'entrée sont reliées aux bornes de ladite source de tension continue et dont les extrémités de sortie sont reliées à un circuit série constitué d'une bobine d'induction (L_1) et d'une combinaison parallèle entre ladite lampe à décharge (10) et un condensateur de découplage (C_1),

l'un desdits premier et second éléments de commutation (Q1, Q2) étant commandé pour être passant et bloqué à une première fréquence, l'autre élément de commutation (Q_2) étant maintenu bloqué durant une première période de temps, pour fournir audit circuit série un courant continu qui est lissé par ladite bobine d'induction (L1) et dont la composante à fréquence élevée est supprimée par ledit condensateur de découplage (C_1), pour fournir ledit courant continu lissé à ladite lampe à décharge lors de chaque cycle dudit courant composite de commande de lampe,

lesdits premier et second éléments de commutation (Q_1, Q_2) étant commandés pour produire et se bloquer alternativement durant une seconde période de temps. alternant avec ladite première période de temps, de manière à fournir à ladite lampe à décharge ledit courant alternatif à fréquence élevée, ayant une seconde fréquence élevée, lors de chaque cycle dudit courant composite de commande de lampe.

8. Circuit de commande à décharge selon la revendication 7, dans lequel ladite seconde fréquence élevée est inférieure à ladite première fréquence élevée, selon laquelle lesdits éléments de commutation (Q_1, Q_2) sont mises à l'état passant et à l'état bloqué pour produire ledit courant continu lissé, ce qui permet audit courant alternatif à fréquence élevée à ladite seconde fréquence d'être globalement amené à ladite lampe à décharge (10).

9. Circuit de commande de lampe à décharge selon la revendication 1, dans lequel ledit premier circuit de commutation dudit moyen découpeur comprend un couple de premier et second éléments de commutation (Q_1, Q_2) et un couple de premier et second condensateurs (C_3, C_4), agencés selon une configuration en demi-pont, dont les extrémités d'entrée sont reliées aux bornes de ladite source de tension continue et dont les extrémités de sortie sont reliées aux bornes d'un circuit série constitué d'une bobine d'induction (L_1) et d'une combinaison parallèle entre ladite lampe à décharge (10) et un condensateur de découplage (C_1),

chacun desdits premier et second éléments de commutation (Q_1, Q_2) étant commandé pour être passant et bloqué à une première fréquence élevée, tandis que l'autre élément de commutation est maintenu bloqué durant une première période de temps, pour fournir audit circuit série un courant continu qui est lissé par ladite bobine d'induction (L_1) et dont la composante à fréquence élevée est supprimée par ledit condensateur de découplage (C_1), en vue de fournir ledit courant continu lissé à ladite lampe à décharge (10), tout en inversant sa polarité d'un cycle au cycle suivant dudit courant composite de commande de lampe,

lesdits premier et second éléments de commutation (Q_1, Q_2) étant commandés pour conduire et se bloquer durant une seconde période de temps alternant avec ladite première période de temps, pour fournir ledit courant alternatif à fréquence élevée, à une seconde fréquence élevée, audit circuit série constitué de ladite bobine d'induction (L_1) est de la combinaison parallèle entre ladite lampe à décharge (10) et ledit condensateur de découplage (C_1),

ladite seconde fréquence élevée étant inférieure à ladite première fréquence élevée, d'une valeur telle que ledit courant alternatif à seconde fréquence élevée est fourni à ladite lampe à décharge (10) lors de chaque cycle dudit courant composite de commande de lampe, tout en permettant à ladite composante à seconde fréquence élevée d'être globalement fournie à ladite lampe à décharge, sans être sensiblement déviée par ledit condensateur de découplage (C_1).

Fig.1

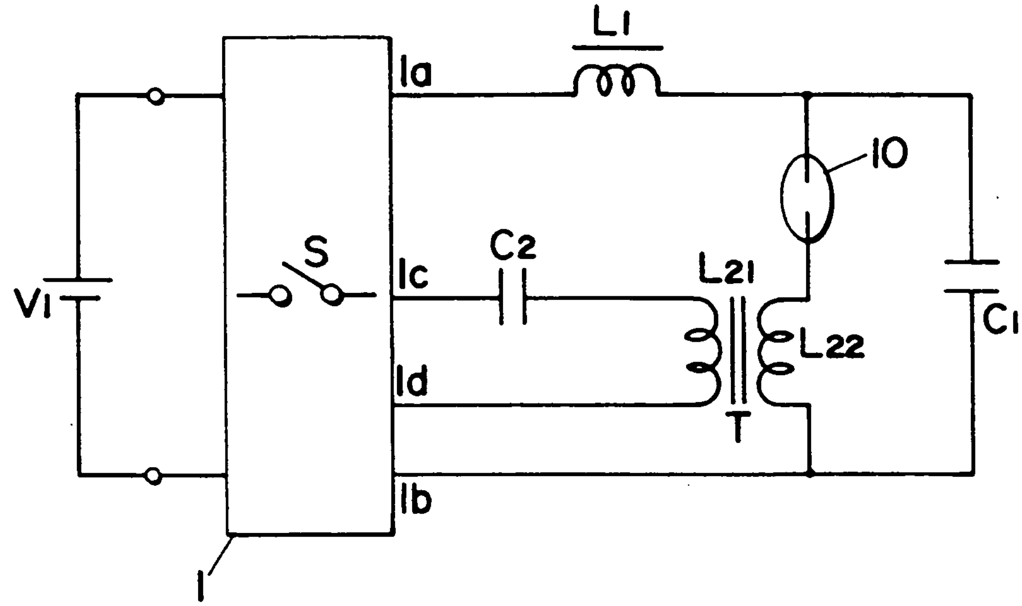

Fig.2

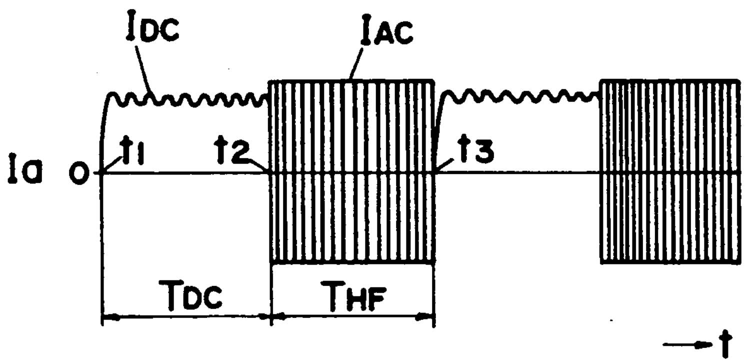

Fig.3

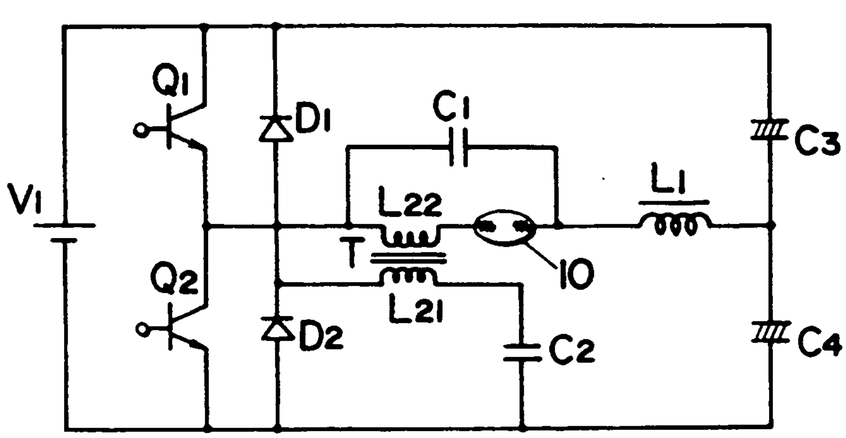

Fig. 4

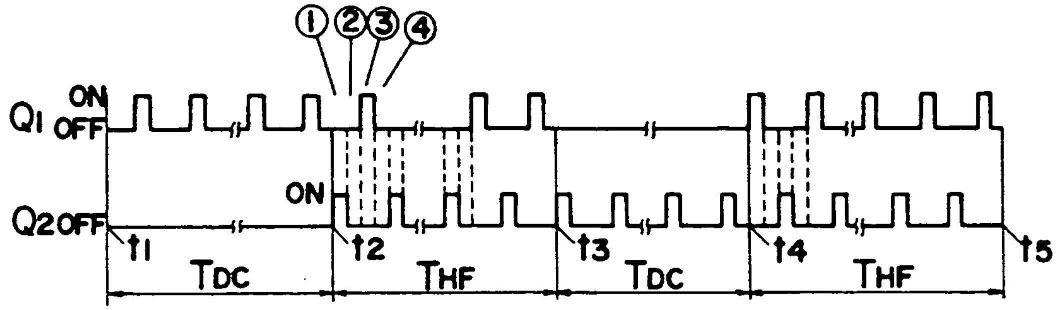

Fig.5

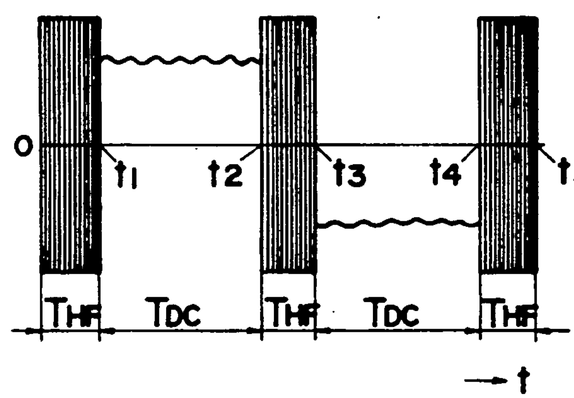

Fig.6

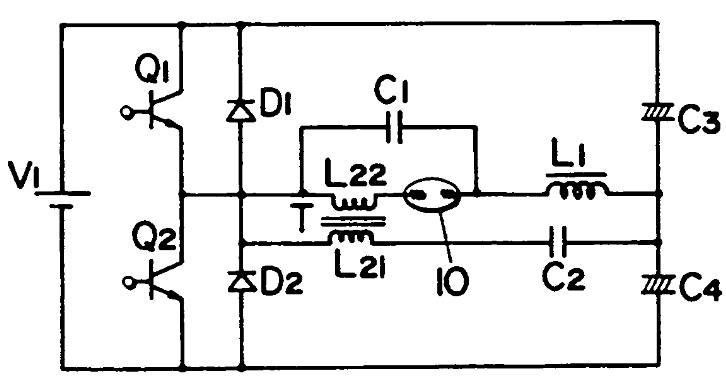

Fig. 7

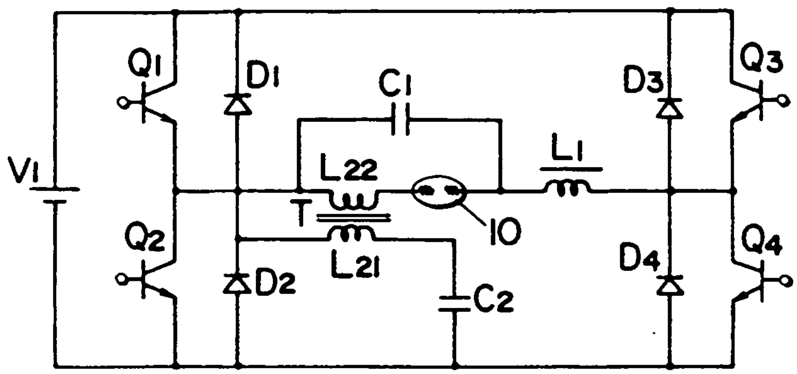

Fig.8

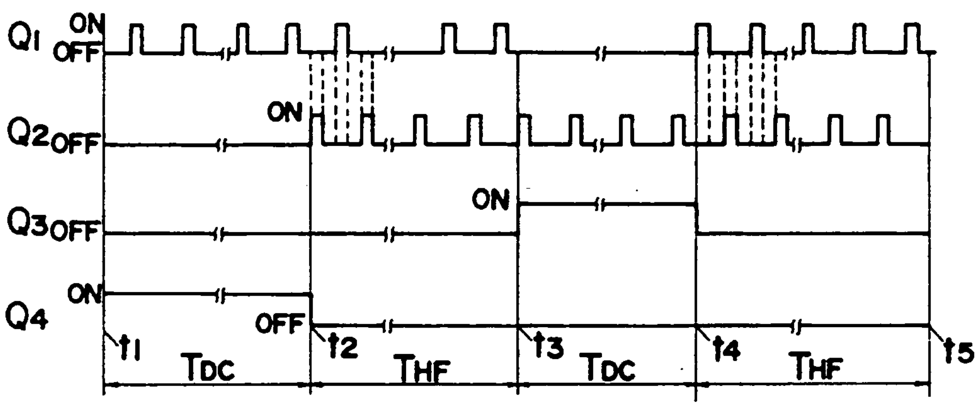

Fig.9

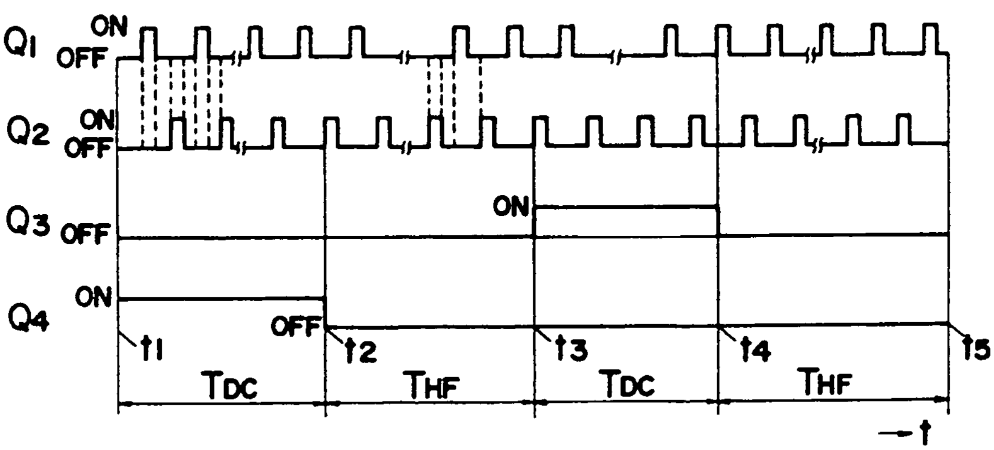

Fig.10

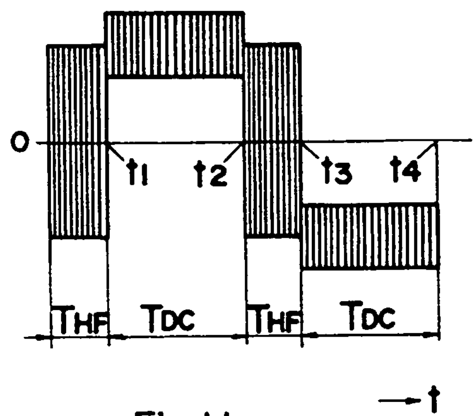

Fig.11

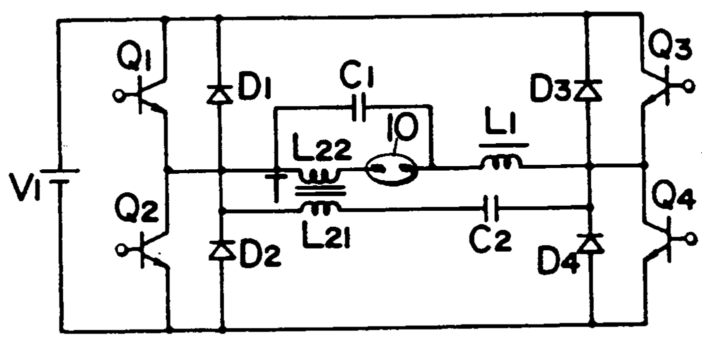

Fig.12

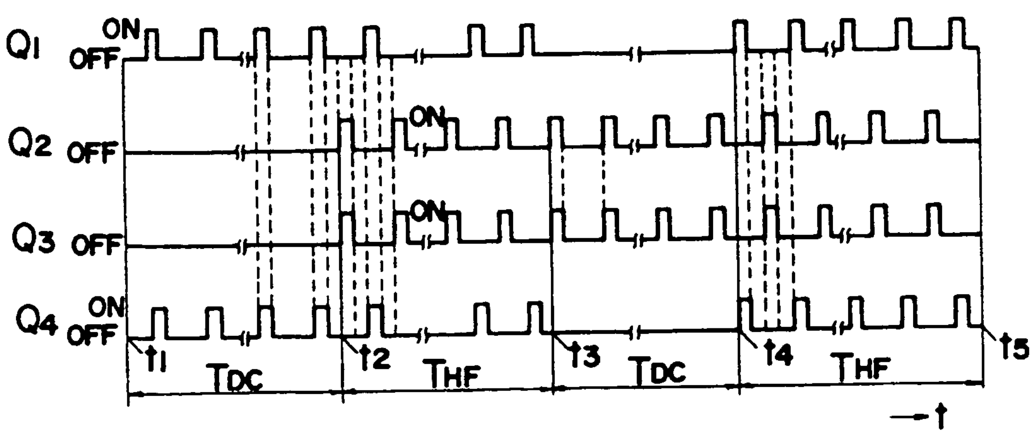

Fig.13

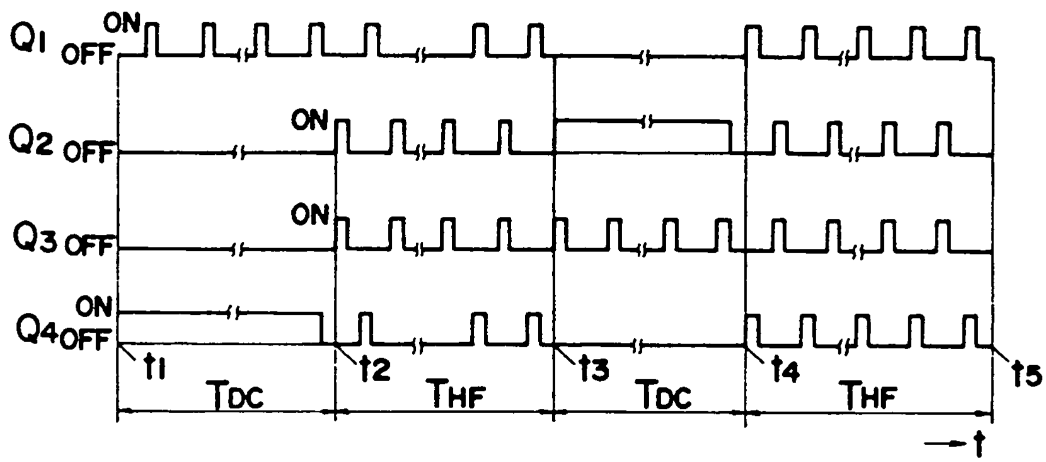

Fig.14

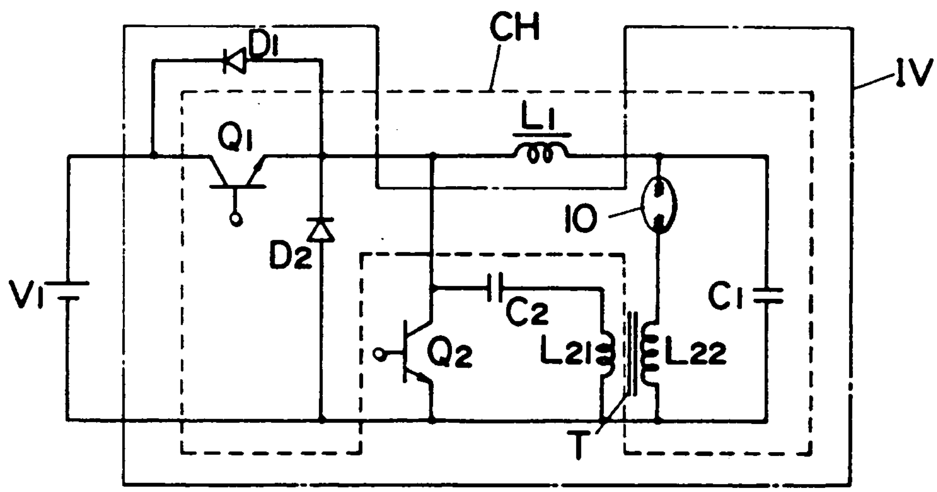

Fig.15

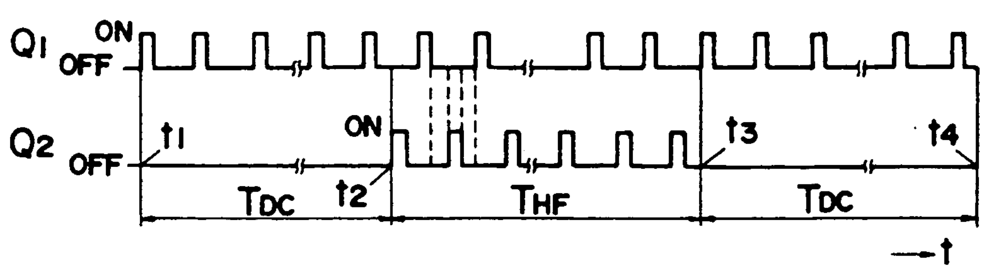

Fig.16

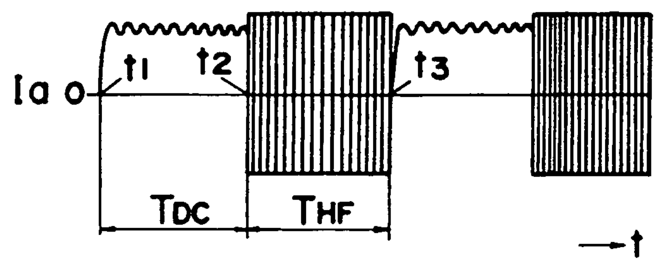

Fig.17

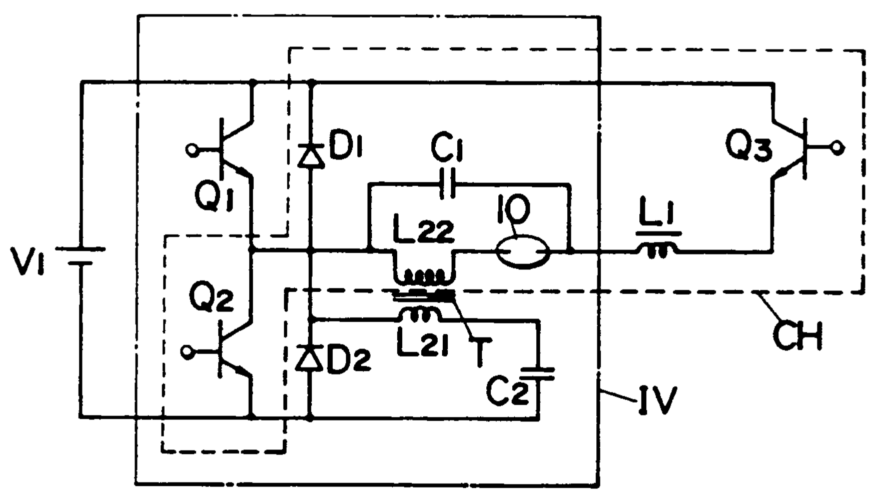

Fig.18

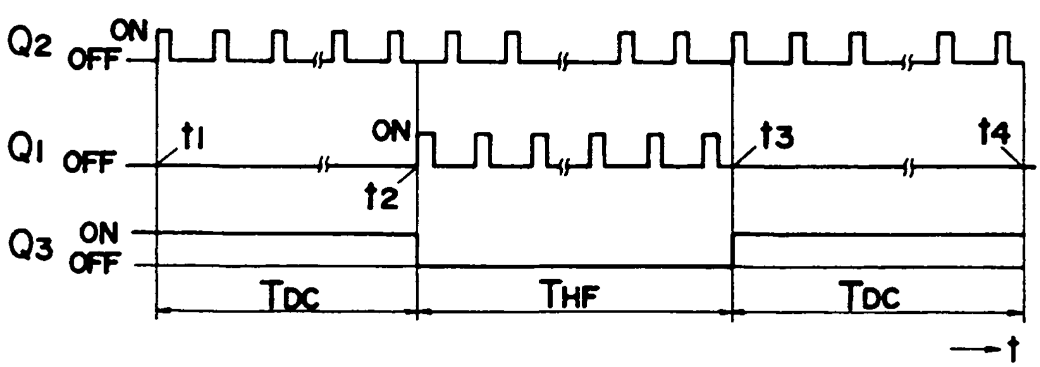

Fig.19

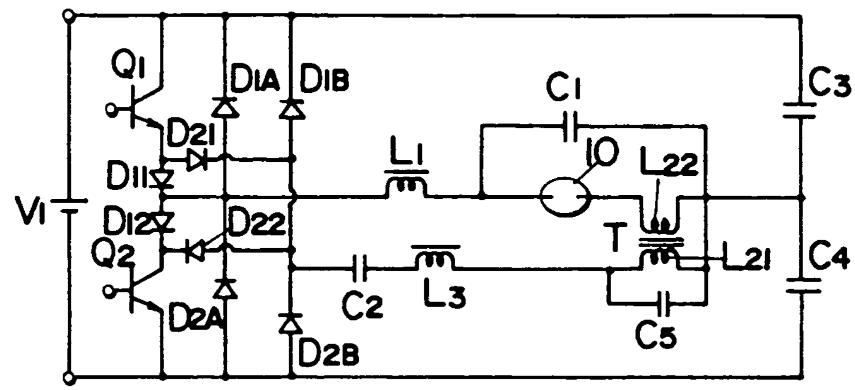

Fig.20

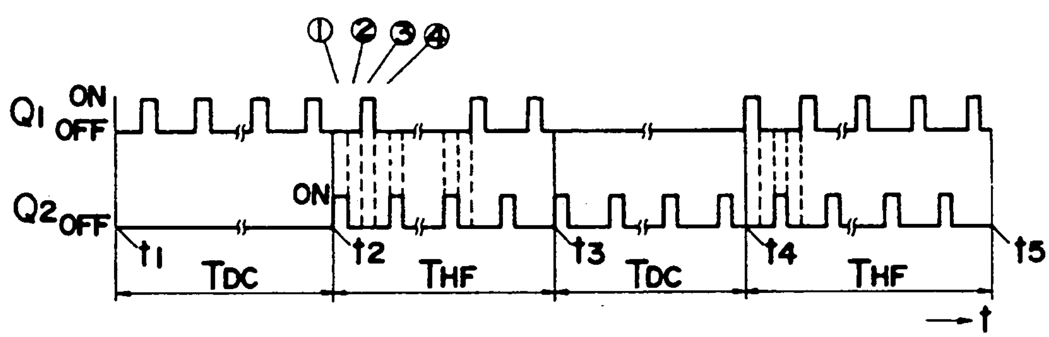

Fig.21

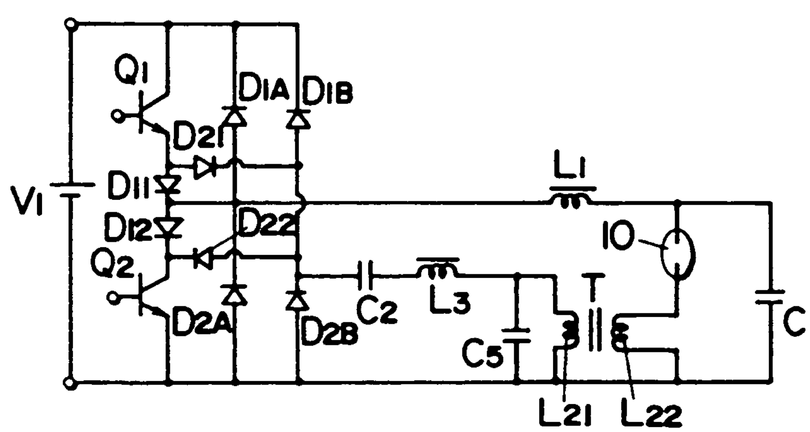

Fig.22

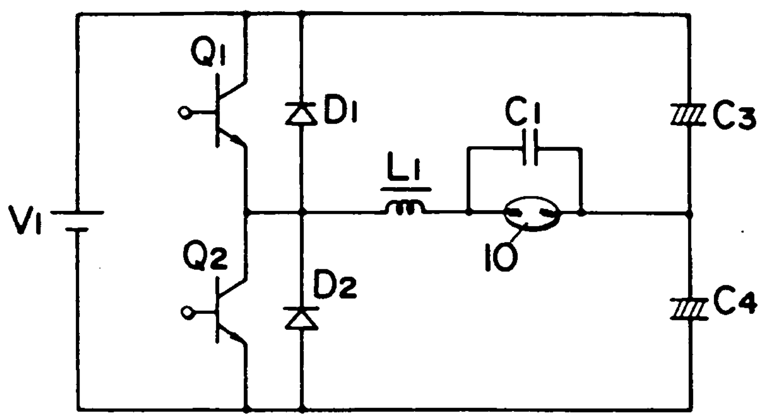

Fig.23

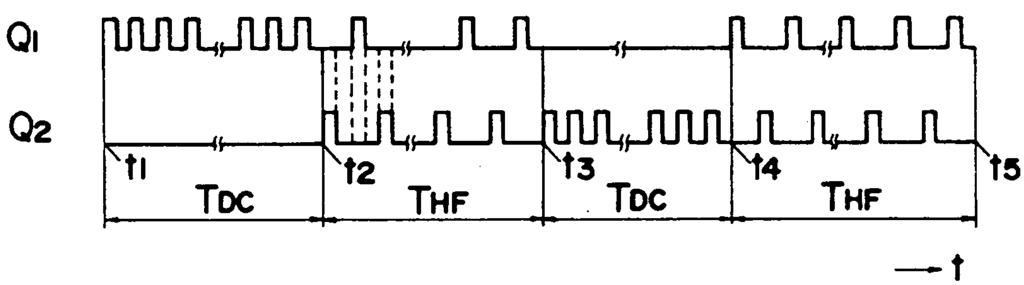

Fig.24

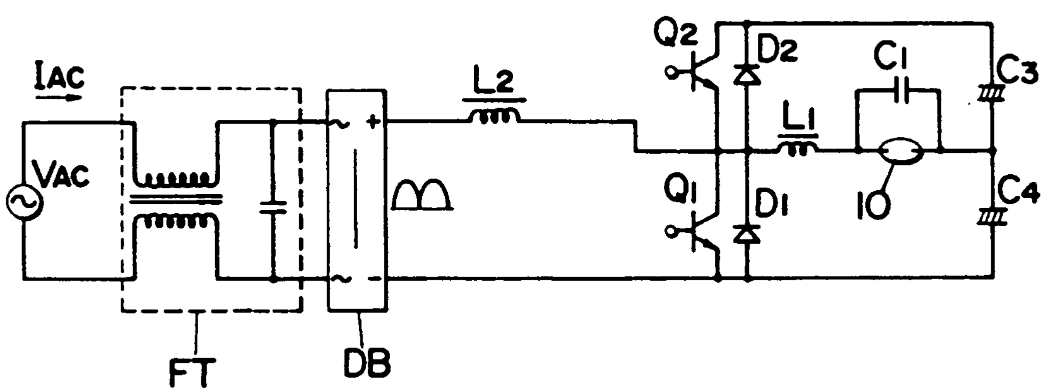

Fig.25

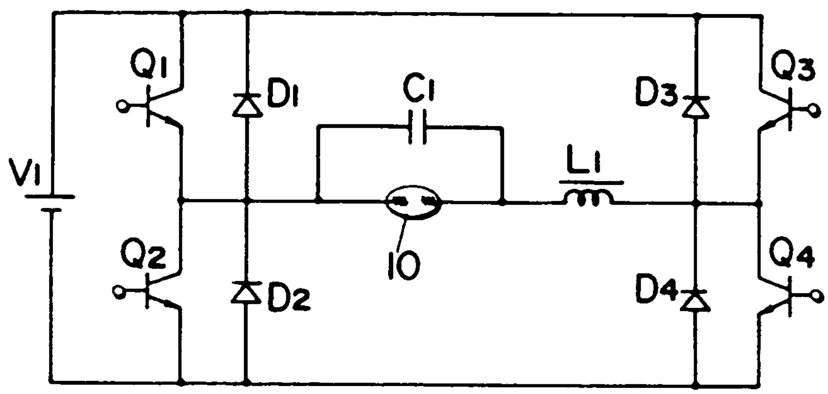

Fig.26

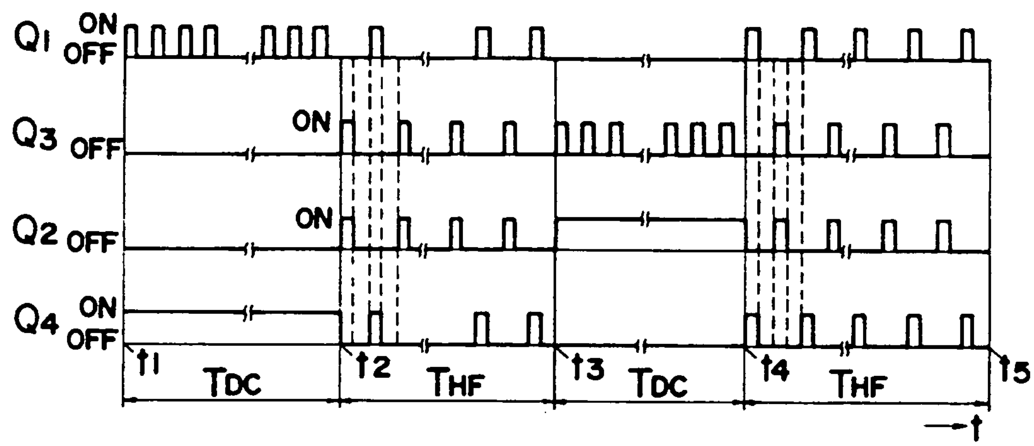

Fig.27